AN

ELEMENTARY COURSE

OF

BOTANY,

STRUCTURAL, PHYSIOLOGICAL,

AND

SYSTEMATIC.

BY

PROFESSOR ARTHUR HENFREY, F.R.S., L.S., ETC.

THIRD EDITION.

BY

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EXAMINER IN BOTANY TO THE UNIVERSITY OF LONDON.

ILLUSTRATED BY UPWARDS OF SIX HUNDRED WOODCUTS.

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ALERE FLAMMAM.

PREFACE TO THE THIRD EDITION.

In the preparation of this edition so much has been added, and so much modified, that to some extent the book may be considered as a new one. Nevertheless, the Editor has, as far as possible, worked on the plan laid down by Prof. Henfrey, and explained by him in the following quotation from the original Preface. Adverting to some remarks made by Sir Joseph Hooker and Dr. Thomson to the effect that

"disservice is done to the cause of Botany by occupying the attention of students in the first instance with the abstract parts of the science,"

Prof. Henfrey remarks, in terms as applicable now as at the time they were first written (1857), that

"The largest class of students of Botany are those who pursue the subject as one included in the prescribed course of medical education. One short course of Lectures is devoted to this science, and three months is commonly all the time allotted to the teacher for laying the foundations and building the superstructure of a knowledge of Botany in the minds of his pupils, very few of whom come prepared even with the most rudimentary acquaintance with the science. To direct the attention of the student to a series of isolated facts and abstract propositions relating to the elementary anatomy of plants, is to cause him to charge his memory or his note-book with materials in which he can take but little interest, from his incapacity to perceive their value or applications. Some of the most important questions of Physiology are as yet in no very advanced state, and the conflicting evidence on many of these cannot be properly appreciated without an extensive knowledge of plants.

"But if we endeavour to seize the floating conceptions furnished by common experience, and to fix and define them by a course of exact practical observation of the more accessible characters of plants (showing the relations of these as they occur in different divisions of the Vegetable Kingdom), we place the student in a position which enables him to proceed at once with an inquiry into the peculiarities of the plants he meets with, and in this way to acquire a fund of practical knowledge, which is not only absolutely requisite before entering on abstract inquiries, but is especially calculated to secure his permanent interest in the study.

"Physiology is undoubtedly of the highest importance, and from its nature is that part of the Science which, were it not for the above difficulties, would with most advantage be taught by Lectures. If the previous education of medical students prepared them, as it should, with an elementary knowledge of the Natural Sciences, we should make Physiology the most conspicuous feature of a course of Botany in a Medical School. In the mean time we subordinate it to the other branches in practical teaching, and in this volume have dealt with it in what we regard as its proper place in the order of study."

Since these remarks were written, and owing in part to the advances made in the Science of Vegetable Physiology, the subject has received more attention in this country, while at the University Examinations greater stress than heretofore is laid upon it. However desirable in one sense this may be, it is at present objectionable, because few or no means are open to the average student of making himself practically familiar with Experimental Physiology. Moreover, the skill in manipulation and microscopical observation required for anatomical or physiological investigations cannot possibly be acquired in the few months devoted to the subject by the majority of students and candidates for examination in the Scientific and Medical Faculties. Sooner or later these defects in the practical teaching of Physiology will doubtless be remedied. In the mean time, practical tuition in Morphology and the rudiments of Classification appears to be the best and most ready method of training a student to observe, to reflect, and to classify.

By its means also the evil effects of the system of loading the memory with secondhand information—of no use whatever outside the walls of the examination-room, and indeed of but little service in the practical examinations (now happily instituted at the University of London and elsewhere)—may be avoided.

In the present edition the additions to the Morphological chapters have been chiefly taken from the writings of Braun, Baillon, Eichler, Warming, Van Tieghem, and others. In this department the Editor has also to acknowledge the valuable assistance rendered him by the Rev. George Henslow, particularly in the sections relating to phyllotaxis and æstivation.

In the arrangement of the Natural Orders the plan adopted by Bentham and Hooker in their invaluable 'Genera Plantarum' has been followed so far as that work extends.

The account of the Cryptogamia has been revised, and that concerning the Fungi written afresh by Mr. George Murray, of the Botanical Department of the British Museum, to whom the Editor would here offer his cordial acknowledgments.

The Physiological Section has been mostly rewritten, and much has been added to it. Use has been made of Sachs' 'Handbuch der Experimental Physiologie der Pflanzen'; of the English and French translations of the 'Lehrbuch,' of the same author—the former published under the superintendence of Messrs. Bennett and Thiselton Dyer, the latter under that of M. Van Tieghem, whose version is enriched with numerous original notes. In addition, the Editor has availed himself of Duchartre's 'Éléments de Botanique,' Dehérain's 'Cours de Chimie Agricole,' and more especially of numerous recent original memoirs published by Boussingault, Darwin, Trécul, Pfeffer, Jauczewski, Corenwinder, Van

Tieghem, Strasburger, Lawes and Gilbert, McNab, Vesque, Rauwenhoff, Warming, and many others whom it is not possible to specify in a work of this character.

Comparatively few alterations have been made to the chapters on Geographical and Geological Botany, which, for their effective treatment, would require another volume. The additions in these subjects have been chiefly derived from the writings of Hooker, Grisebach, Tchihatchef, Williamson, Crépin, and Carruthers.

Some additional woodcuts have been supplied, whose source is acknowledged in the text.

M. T. M.

March 1878.

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AN

ELEMENTARY COURSE

OF

BOTANY.

GENERAL INTRODUCTION.

Sect. 1. OBJECTS AND SUBDIVISIONS OF THE SCIENCE.

Botany is that department of Natural Science which deals with Plants, their conformation, life-history, relations one to another and to the universe of which they form a part. No absolute distinction can be drawn between plants and animals.

At the outset we must be content with the conception of a plant as furnished by the previous experience of the student; this will be enlarged and at the same time rendered clearer by the study of the following pages; and, after the more important principles of physiology have been expounded, a clearer notion of the relation of plants to other living beings as well as to unorganized or mineral substances may be obtained.

Botany is divisible into two principal departments:—the *Natural History of Plants*, which deals with the characteristic phenomena presented by the individual kinds of plants; and *Philosophical Botany*, the object of which is to ascertain the general facts and laws which pertain to more or less considerable assemblages of plants.

Philosophical Botany represents the pure science; and it is with the departments of this we have chiefly to do in this work. The Natural History of Plants, which in early times constituted the whole science, resolves itself, at the present time, into a number of distinct branches of *Applied* or *Practical Botany*.

Philosophical Botany includes the following departments:—

I. *Morphology*, or the *Comparative Anatomy* of plants, consisting of the study of the outward forms of the diverse parts of plants.

II. *Elementary* or *Philosophical Anatomy*: the study of the tissues of which plants are composed, and the intimate structure of their several parts.

With these two is conveniently associated the *Terminology*, or technical language of Botany.

III. *Physiology*: the study of vital phenomena, or of those processes and actions performed by the living plant, including those specially characteristic of plants, and also those which are common to the animal kingdom, as well as the consideration of the general physical agencies pertaining to the mineral kingdom equally with the two others.

IV. *Classification*, which is the study of the mode of arranging the kinds of plants in groups and series of groups either "artificially," when convenience and facility of study are the chief aims, or according to their supposed lineage and kinship, and thus to express in an abstract form their mutual relations and their degrees of perfection in organization. This department includes the *Principles* of *Descriptive Botany* and of the *Nomenclature* of kinds and classes of plants.

Applied Botany is divisible into many departments. That most closely connected with Philosophical Botany is *Descriptive Botany*, which is the art of describing the particular kinds of plants in technical language, in such a manner that they may be readily recognized by botanists. Special works are commonly devoted to this branch, and are very commonly confined to the plants of a limited area, as a particular country or even province; such books are called *Floras*. *Pharmaceutical Botany* treats of the medicinal, nutritious, or poisonous properties of plants. Vegetables possessing such properties are generally included under the head of *Materia Medica*, to which subject special treatises are also devoted. *Agricultural*, *Horticultural*, and *Economic Botany* are often treated as distinct subjects: the first two are founded on the application of the principles of Physiological Botany; the last on the ascertained facts of Comparative and Elementary Anatomy, and on the combination of these facts with chemical and mechanical knowledge.

None of these departments of Applied Botany receive separate treatment in this work, although incidental reference is made to them to indicate the application of the laws and facts of Philosophical Botany to them.

Botanical Geography and *Botanical Geology* (or *Palæontology*) are mixed studies, founded on the association of the results of pure and of applied Botany with those of other sciences: the first is related most closely to Physiological Botany, but has some problems *sui generis*, to be solved only by independent facts and observations; the second has some very interesting relations with the Scientific Classification of plants. These two departments, as applications of the science, have a peculiar philosophical interest, but can only be very briefly alluded to in this volume.

In the present work, the different departments are treated of in the following order :—

Part 1. MORPHOLOGY, or COMPARATIVE ANATOMY OF PLANTS. 2. SYSTEMATIC BOTANY. 3. PHYSIOLOGY, including PHYSIOLOGICAL ANATOMY. 4. GEOGRAPHICAL and GEOLOGICAL BOTANY.

SECT. 2. METHODS AND MEANS USED IN THE STUDY OF BOTANY.

Examination of Plants.—The study of the morphology of plants, to which the first Part of this volume is devoted, necessitates little more than a supply of fresh specimens, a penknife, two or more needles mounted in handles, and a pocket magnifying-glass of moderate power. One of the needles should be of the ordinary form, and others with a flat top with a cutting-edge like a hare-lip pin. Roots, stems, and leaves require little or no preparation; and the dissection of most flowers is a very simple operation. The majority of the characters of many flowers may be observed by simply removing successively the parts with a penknife, and by examining them in perpendicular and cross slices. In any case care should be taken to detach and observe the parts in regular order, so as to ensure an accurate knowledge of the way in which the different parts are arranged. Perpendicular sections of entire flowers made through the centre and from below upwards are very instructive; and horizontal sections through unopened buds, both of leaves and flowers, are likewise necessary for the examination of the relative position of the organs and of the way in which they are packed. When flowers are extremely minute, and also for the investigation of the structure of ovules and seeds, a pocket-lens mounted on an upright bar, or a *simple microscope*, becomes requisite. The latter instrument consists essentially of a stand, provided with a movable arm supporting a magnifying-glass over a stage upon which the object is laid, so that both hands may be at liberty for its dissection. The stage is an open frame, upon which a slip of glass rests; and the object to be examined, lying on the glass slip, may be illuminated by a small mirror beneath sending light *through* it, or, if required, by a condensing-lens at the side bringing a bright spot of converging rays *upon* it. The dissection is effected with a fine dissecting scalpel and needles. By their means the parts of the flower can be separated one from another so as to show their numbers, form, combination, and position with regard one to another.

In pursuing the study of Systematic Botany, the same means are used, the only difference being that the investigation of each

flower is carried out in detail, and in comparison with others, so as to ascertain all its characters, with a view to determine its special peculiarities and its relations to other plants. It is a very useful and improving exercise for the student to make drawings, however rough, of what he sees, to make a thorough examination, and to write down in full the appearances of the plants he meets with, before searching in books for their names, and also to do the same with known plants, and then to compare the characters thus drawn up with those given in authentic works. Further instruction as to the mode of describing plants and the use of schedules as required in most examinations is given in the section devoted to the description of plants.

To those who follow out Systematic Botany in detail, and wish to gain acquaintance with the species of plants, it becomes necessary to have access to a *Herbarium*—that is, a collection of plants so dried that the specific characters, at least, are preserved. In many cases, if the drying has been carefully effected, the generic characters may be ascertained by soaking the flowers in boiling water, when they become softened and the parts separable, like tea-leaves after infusion. Herbaria furnish materials for the comparison of plants, as it is seldom that a number of species of one genus can be obtained either wild or in gardens in a fresh state at one time. Persons living in the country, and studying the British plants, will find it indispensable to form a collection of dried specimens.

How to dry Plants.—Plants are dried by laying them out smoothly when fresh between several folds of paper (either stout blotting-paper, or, still better, what is called "Botanical paper," made for the purpose), and submitting them to pressure by means of weights laid on a board. The damp paper must be frequently replaced by dry sheets; and when the plants are quite dry, they may be fixed to half-sheets of white paper, with a little thin glue, or by simply attaching them by bands of gummed paper, or by stitching. The best kind of paper is stout white cartridge, of *demy* size; some prefer a stout writing-paper, rather smaller, of the same size as lawyer's "draft"-paper. Only one species should be placed upon one half-sheet; the name should be written on the lower left-hand corner. The half-sheets containing the species of a genus may be placed in a sheet of the same paper, the name of the genus being written outside, likewise at the left-hand bottom corner. These sheets may be kept in drawers or in pigeon-holes of a cabinet, or may be tied up in bundles, between covers of stout pasteboard. It is advisable to poison the dried plants with a solution of corrosive sublimate in spirits of wine, as some of them are very liable to be

devoured by insects of various kinds*. Plants preserved in herbaria, especially if rare or local species, should always have the time and place where they have been gathered carefully noted.

Anatomical Study.—The study of the Elementary Anatomy and the Physiology of Plants opens up a far more extensive field for the employment of instruments and technical manipulations. First of all a *compound microscope* is an essential. For the student, magnifying-powers of 1-inch, ½-inch, and ¼-inch are amply sufficient, although the more abstruse questions require the most perfect and powerful instruments that can be obtained. For general students' use the binocular microscope has no advantage over the ordinary instrument.

The tissues of plants are observed for the most part by means of extremely thin slices passing in various directions through the structures. These are usually best made with a razor. Stems, pieces of wood, and other firm objects, when being cut, may be held in the finger and thumb of the left hand; delicate and thin structures, like leaves &c., should be placed between the two halves of a split cork, or rolled round the edge of a cork, and the cork supported by sticking it in the neck of a vial or test-tube, which serves as a handle. Seeds and similar small objects may be fixed, for slicing, on a piece of white wax. Where it is not imperative to examine the tissues *in situ*, small portions may be softened by boiling in water.

Sometimes it is useful to obtain preparations by macerating the softer tissues, either in water or weak acids. In the case of woody structures recourse may be had to an operation which requires a little care: a fragment of the wood should be placed in a watch-glass with a morsel of potassic chlorate, to which a drop or two of nitric acid is added by means of a glass rod, the whole being gently heated for a minute or two, and water being poured on to prevent complete solution. The fragments macerated in any of these ways being placed on a slip of glass beneath the simple microscope, the elementary organs may be picked out with a needle or extremely fine camel-hair pencil, under a simple lens of ½- or ¼-inch focus, and removed to a clean slide.

The thin slices, or the fragments of macerated tissues, should be laid upon a slip of glass, a drop of water added, and a thin glass cover laid on. They may then be examined under the compound microscope. Objects of microscopic dimensions, such as minute Algæ, Fungi, pollen-grains, &c., require no preparation.

* The mixture in use at the Kew herbarium consists of corrosive sublimate one ounce, carbolic acid one ounce, methylated spirit two pints; mix. It must be used with great care, owing to its poisonous qualities.

To render tissues transparent they may be soaked in a dilute solution of caustic potash for a few minutes. If by this means made too transparent, the tissue should be immersed in a dilute solution of alum or of hydrochloric acid.

It is very instructive to apply chemical reagents of various kinds to the objects lying in water upon the microscopic slide. Dilute sulphuric acid is often useful to coagulate protoplasmic structures and to clear delicate tissues; when this is added first, and afterwards solution of iodine, the younger cellular structures turn blue, while the older ones become deep yellow. Iodine alone colours starch-grains blue. Sugar and nitric acid colour the protoplasmic structures red. These reagents may be applied by means of dropping from a glass rod or fine tube. It is often advantageous to soak the sections for some hours in a solution of pure carmine in ammonia diluted with water. The nuclei and cell-contents become tinged with the carmine, and can thus be more readily distinguished from the cell-wall. More particular reference will be made to them in the chapters on Anatomy. Microscopic preparations of soft vegetable structures are best preserved in glycerine or strong solution of calcium chloride. Some objects are advantageously mounted in Canada balsam; these must be well dried first, and, for a few days previously to mounting, should be soaked in spirits of turpentine. Those who desire to obtain minute instructions on the manipulations necessary for the study of Vegetable Anatomy, may consult Schacht's 'Microscope,' translated by Currey, or the articles on these subjects in the 'Micrographic Dictionary.'

In physiological investigation various pieces of philosophical apparatus are requisite. It is also often necessary in studying the life-history of plants, especially the lower ones, to grow them under different conditions and to watch them in their several stages. For these purposes special appliances and chemical solutions are needed.

Lastly the student must remember that Botany is not an "exact" science. Rarely, if ever, can a definition be framed in any branch of natural history which is not subject to frequent and considerable exception. These exceptions arise from the natural variations which occur in all living organisms, either in accordance with existing circumstances or as hereditary tendencies. Again, it must be borne in mind that Botany is a progressive science, and therefore that the language and terminology in general use is not always strictly accurate according to the most advanced state of science; hence many of the terms have to be taken in an arbitrary or in a conventional sense.

PART I.

MORPHOLOGY,

OR

COMPARATIVE ANATOMY.

CHAPTER I.

GENERAL MORPHOLOGY.

General Remarks.—The functions of plants being comparatively simple, and, to speak in general terms, limited to those of nutrition and reproduction, the physiological classes of organs are few. The immense diversity which presents itself in the Vegetable Kingdom depends chiefly upon varieties in the form of organs performing similar functions. In addition to this, the organs of plants are displayed externally, not enclosed in cavities or surrounded by an integument or shell like that of animals, so that the external forms of plants furnish a guide to the discrimination of their most essential characters.

Plants are destitute of the nervous system and the organs subservient to it, and are without the connected system of blood-vessels, by which, in the majority of animals, the unity and interdependence of the nutritive processes are maintained. Plants consist simply of organs of absorption, assimilation, respiration, and reproduction, all composed of comparatively uniform elementary tissues, and supported by a solid framework or skeleton, which is more strikingly developed according to the number of organs associated in one community, and more diverse in its mode of construction according to the variety and complexity of the physiological kinds of organs.

The organs of plants are not only of few physiological kinds, but their variations in form depend on secondary modifications of a very few fundamentally diverse elements. The object of Vegetable Morphology is to ascertain what these elements are, and to trace

out the laws under which they acquire the different forms which they present in fully developed plants.

The methods of Morphology consist in the comparative study of the forms of organs throughout extensive series of plants, the study of malformations arising from arrested, excessive, or perverted growth *(teratology)*, and the study of the progressive development of plants from their embryonic forms (*organogeny*).

Simplest Plants.—The simplest plants (fig. 1) consist of solitary *cells* or bladders of membrane containing a viscid fluid called *protoplasm*, in which latter the vitality of the plant is concentrated. By the aggregation of such cells into threads, tubes, plates, spheres,

Fig. 1.

Simple cellular plants.
A. Yeast-plant vegetating. C. *Penicillium glaucum.*
B. *Aspergillus glaucus.* D. *Mucor Mucedo.*
Magnified 200 diameters.

and other forms (fig. 1, A, B, C, D), a gradually increasing complexity is brought about.

Higher Plants.—What are called the higher classes of plants, those most familar to uninstructed persons, are constructed of precisely the same elements, but exhibit the greatest morphological complexity. The highest class of plants have conspicuous flowers,

as in a rose or a tulip, and in their fruit or seed-vessel are one or more *seeds*—hence the name *Phanerogamia*, or *Flowering Plants*. The complexity of their structure arises not from the number of the organs, but from the more clearly defined limitation of the various physiological functions to the different organs, which are thus more specialized. At the same time the organs are, anatomically speaking, more intimately combined together into a connected whole, and the reproductive powers are more individualized and concentrated at particular centres.

The foregoing may be comprehended by contrasting any ordinary Flowering plant, having distinct blossoms and seed-bearing fruit, with a Fern, where the fruit is borne upon leaves generally of the usual character, and again with a Seaweed or a Lichen, in which there is not even any distinct separation between stem and leaf-structures, and wherein no leaf-buds exist.

In Flowering plants we readily distinguish, in all stages of life beyond the very earliest, two distinct kinds of growth, viz. a stem or axis, from the sides of which proceed lateral organs, of various, but always definite kinds and forms, such as leaves, &c., which become what are called its appendages. In Seaweeds, Lichens, and Fungi there is no really similar diversity of parts: the axis alone is represented, always devoid of leaf-buds, and therefore of proper appendicular organs, the axis itself assuming most varied forms, often more or less approaching those of true leaves, but never exhibiting a distinct separation into two kinds of vegetable structure such as characterizes the higher plants. A distinctive name is given to that class of axes which exist without appendicular vegetative organs. Such products as the leaf-like expansion of Seaweeds, the scale-like plates or crusts of Lichens, or the flocculent "spawn" of Fungi, performing at once the functions of stem and root and leaf, represent what is technically termed a *thallus* (fig. 1). Plants characterized by the possession of this kind of vegetative structure are called Thallophytes, and are contrasted with all the higher plants exhibiting the coexistence of stem and leaf, which are called Axophytes or Cormophytes (from *cormus*, a stem).

But the Cormophytes are again distinguishable into two very well-marked groups, by the characters of the reproductive organs, which, moreover, connect the lower of the two groups with the Thallophytes. The Thallophytes and the lower Cormophytes (including Mosses, Ferns, and allied classes) are reproduced by *spores*, simple structures performing the office of a seed, but in which no *embryo* or rudimentary plant exists at the period when they are thrown off by the parent. The higher Cormophytes are reproduced by true *seeds*, which are far more highly organized bodies than spores, and

which are especially characterized by the presence of an *embryo*, or rudimentary plant, which is developed within them while the seed is still contained in the parent fruit. The latter division also is characterized by the possession of flowers, while the spore-bearing Cormophytes are flowerless, like the Thallophytes.

By far the greater portion of the plants useful to man belong to the Phanerogamous division; and this includes also the most conspicuous and familiar forms of vegetation, those most easy to procure and most easy to study. Hence it is desirable that the Flowering plants should occupy a principal place in an elementary work, and, moreover, that they should be examined in the first instance, before the student is led into the study of the more obscure and minute characters of the *Cryptogamia*. But the study of Cryptogamous plants is quite indispensable to the physiologist; while it forms a most interesting department of the morphology of plants. It will be found most convenient, however, to defer the study of the *Cryptogamia* till after a general acquaintance has been obtained of Flowering plants.

CHAPTER II.

MORPHOLOGY OF THE PHANEROGAMIA.

Sect. 1. General Observations.

General Construction of Flowering Plants.—In any ordinary Flowering plant we may readily recognize some of the most important characters of the organization. Taking the plant as a whole, we find a *stem*, furnished below with *roots* to fix it in the ground and absorb nourishment, and clothed above with green *leaves*, which are known to be the organs of respiration and digestion. Taken together these constitute the system of *vegetative organs*, more or less complicated in their development and arrangement in different cases, and concerned in the nutrition and enlargement of the individual plant (in the familiar sense of that term). At certain seasons we find, superadded to the foregoing, a system of organs constituting the *inflorescence*, and consisting of the *reproductive organs*, provided for the production of *seeds* (the "eggs," as it were, of plants), from which new independent individuals may be raised.

The *inflorescence* consists of one or more *flowers*, which, as will be shown hereafter, are composed of various kinds of peculiarly modified foliar appendages, or *phyllomes*, more or less blended together into compound organs. For our present purpose it will suffice to describe the general and essential characters of the parts found in true flowers.

The outer covering of complete flowers consists of a circle of leaf-like organs, most frequently of green colour, and often forming a kind of cup; this cup or circle of leaf-like organs is called the *calyx*, and its component parts are the *sepals*. Within the calyx of complete flowers we find one or more circles of ordinarily larger, but more delicate, and generally brightly coloured leaves; these are likewise united together below in many flowers: they form collectively the *corolla*, and the individual parts are called *petals*.

Fig. 2.

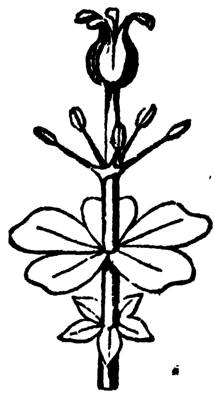


Diagram illustrating the composition of a flower, of four circles of organs—sepals below, followed by petals, stamens, and carpels, all arising from a prolonged axis or thalamus.

Examples of the above may be found in the Heartsease, the Wallflower, the Primrose, &c., where there exist a green calyx and a coloured corolla. In the Tulip the outer parts of the flower consist of six similarly coloured organs, resembling ordinary petals; while in the Dock they are six greenish sepal-like organs. A close examination shows, however, that both kinds of organs stand in two circles of three, one within the other: hence many authors regard them as representing a calyx and corolla of like structure. Other authors give the double circle the collective name of *perianth* or *perigone*.

The *calyx* and *corolla* have no essential share in the production of the seeds; they merely surround and protect the more important organs, either temporarily, or as entering more or less into the composition of the fruit, and sometimes they serve to attract and retain the insects by whose agency the flower is fertilized and the seed formed. The collective term *floral envelopes* is commonly applied to the calyx and corolla taken together; and either one or both of these may be absent in flowers which are nevertheless perfectly capable of producing seeds.

Within the petals is placed the *andrœcium*, consisting of the *stamens*, or male organs of flowers. Each stamen consists of more or less club-shaped bodies called *anthers*, usually supported upon thread-like stalks called *filaments*. The essential character of an anther

is that it contains, and ultimately discharges, the fine dust-like sperm-cells or fertilizing globules called *pollen*.

The centre of the flower is occupied by the *gynœcium* or *pistil*, the female or seed-bearing part of the flower. Pistils are formed of foliar organs corresponding to sepals, petals, and stamens, and called *carpels*; but these are not always so readily distinguishable, on account of their varying number and degree of union, consequent upon their being crowded at the apex of the flower-stalk. The distinguishing character of a carpel is that it bears *ovules* or rudimentary seeds containing germ-cells.

As the stamens furnish the pollen by which the germ-cells are rendered fertile, the two sets of organs, stamens and carpels, are considered *essential organs* of flowers, without which the purpose of the whole structure could not be performed.

In some flowers, such as those of the Hydrangea and the Snowball-bush (*Viburnum Opulus*), there is a tendency in cultivation to the abortion of the stamens and pistils; so that the flowers become *neuter*, or totally barren. But in many plants it is the natural condition for the stamens to occur in distinct flowers from the pistils, so that the individual flowers are imperfect, male or female: we have examples of this in the plants of the Cucumber family, and also in most of our native forest-trees, such as the Oak, Beech, Hazel, or even on entirely different plants, as in the Willow and Poplar, &c.

The *carpels*, the essential organs of a female flower, occur in two conditions in Flowering or Seed-bearing plants; and these two conditions form the basis for the primary subdivision of this group.

In by far the majority of flowers the carpels are folded up and their edges united so as to form hollow cases, in the interior of which the ovules are enclosed. In such instances the pistil is divisible into regions, of which the lower hollow portion, called the *ovary*, is the most important: very frequently a stalk-like process, the *style*, is prolonged upward from its summit, terminating above in a more or less thickened head, called the *stigma*, which marks the position of an orifice leading down through the tubular or spongy tissue of the style into the cavity of the ovary. In many cases the *stigma* is seated immediately upon the top of the ovary, without an intervening style (Poppy, Tulip). Plants bearing their ovules in such closed ovaries are called *Angiospermous*, or covered-seeded.

In Pines, Firs, the Yew, Juniper, and in the exotic family of the Cycads, the sexual organs occur in distinct flowers: and these flowers are not only devoid of proper floral envelopes, but are reduced respectively to single stamens and single carpels, mostly collected into male and female *cones*. The anthers of the male cones

produce *pollen*, and the carpels of the female cones produce *ovules*; but the carpels occur in the form of open scales, and the ovules are borne upon the surface or the free margins of the carpels, so that the pollen reaches them at once, without passing through a stigma and style. Plants with flowers of this kind, with which are also associated many peculiarities in the mode of development of the embryos, are called *Gymnospermous*, or naked-

Much difference of opinion still exists among botanists as to the true nature of the female flower in Gymnosperms; but for the present the above explanation will suffice for the student.

The *Angiospermia*, comprehending the great body of the Flowering plants, are separable into two very natural groups, which are plainly distinct in the mass, although many complex relations exist between them. Distinctive characters of the two divisions may be found in many parts of the organization of the majority of the plants; but the most general difference is that which occurs in the structure of the *embryo* contained within the seed.

In one division we find that the seeds, with few exceptions, contain an *embryo* in which we may distinguish *two* rudimentary leaves, or *cotyledons*, applied face to face, and having the terminal bud, or growing-point of the stem, enclosed between them. In the other division the embryo presents but *one cotyledon*, or seed-leaf, more or less rolled round the bud, like a sheath. The plants of the first division are called *Dicotyledonous*, those of the second *Monocotyledonous*.

Dicotyledons and Monocotyledons are naturally divided from each other not only by the general characters of their mode of germination, but by the structure of their stems, the arrangement of the skeletons or veins of their leaves (net-veined in Dicotyledons, parallel or straight-veined in Monocotyledons), and the number of organs in the circles of the flowers (generally in fours or fives in the one case, and in threes in the other). These distinctive characters will be more fully considered hereafter.

The ripe seed of the Gymnospermia is very much like that of Dicotyledons; but the leaves of the embryo are either more numerous, or if but two are present, they are sometimes, but not always, slit into lobes, whence these plants have been called Polycotyledonous.

The germination of the seeds of all the Flowering plants consists in the emergence of the *embryo*, more or less completely, from the seed, and in the unfolding of its rudimentary vegetative organs—the *radicle*, the *cotyledonary leaf* or *leaves*, with the *stem* supporting them, the *tigellum*, which is sometimes very short, but which termi-

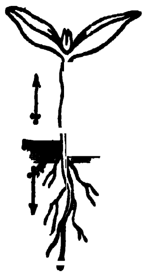
nates above in a little bud called the *plumule*; the subsequent unfolding of the plumule gives birth to the first true leaves (fig. 3). Here, then, we have represented all the kinds of organs of vegetation which will form the first objects of our investigation, namely the *root*, the *stem*, and the *leaf*, together with the *buds*, or compounds of rudimentary stem and leaves, which occur at all growing-points of the plants possessing these organs.

The phenomena of germination may be conveniently observed by sowing some Turnip-seeds and Oats in a saucer of moist sand covered by a bell-glass. The structure of a dicotyledonous seed may also readily be observed by soaking a Pea or a Bean in water, and then peeling off the rind, when the parts of the embryo, as above described, may be readily observed.

Sect. 2. The Root.

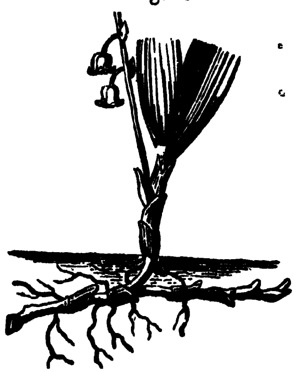
Definition.—The root may be described in general terms as the descending portion of the axis, destitute of leaves, buds, flowers, and green colouring-matter, but provided originally with a minute "root-cap" at its extremity. Another character of general although not of universal application is, that it is the part of the plant which penetrates into the soil, and which serves at once as an organ of attachment and of nutrition.

Fig. 3.



A seedling Dicotyledonous plant, with an ascending axis or tigellum and a descending axis or radicle, two cotyledons, and a terminal bud or plumule.

Fig. 4.



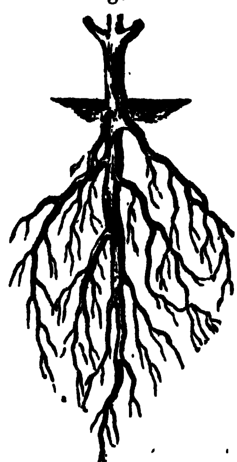
Lily of the Valley (*Convallaria majalis*), with a subterraneous creeping stem and adventitious roots.

The simplest representative of the root is a mere cell or tube capable of absorbing fluids. Such organs are found in the simplest plants. The definition above given applies to the more highly organized plants; but even in these the *root-hairs* are mere cells of the character just mentioned.

Exceptions.—The statement that roots descend is subject to a few exceptions in the cases of the lateral ramifications of roots, and of the lateral roots formed by parasitical and by certain climbing plants, which often retain their original direction, making a more or less obtuse angle with the stem from which they rise. In some Cycads and Arads the root-branches ascend vertically. These exceptions are less numerous than the deviation of the stem from its general character as the ascending part of the axis, since in a large number of perennial plants the direction of the main stem is constantly horizontal. Stems of this kind are of frequent occurrence among perennial herbaceous plants, and are ordinarily termed by gardeners "creeping roots:" for example, those of the Lily of the Valley (fig. 4), Garden Flag, Couch Grass, &c. Roots, as a general rule, are destitute of leaves and leaf-buds, which fact serves to distinguish them from *rhizomes* or *root-stocks* (STEMS). But the distinctions between root and stem are not absolute: many exceptional instances occur, and some transitional ones; thus, under certain circumstances, roots, as indeed every part of the vegetable structure, may be made to form buds, but always from the sides, never from the end as in stems. Some trees are especially prone to this, and may be propagated by cuttings of the root, such as *Pyrus japonica*, *Maclura aurantiaca*, the Plum-tree, &c. The root of *Anemone japonica* likewise produces buds very readily. The roots of *Neottia* bear leaves, while, on the other hand, some Orchids, as *Epipogon Gmelini* and *Corallorhiza innata*, and some Bromeliads have no roots.

Origin of the Root.—The true root of the embryo plant is the downward continuation of the axis; but the original radiclè, the real inferior extremity of the axis in the Monocotyledons and in the stem-forming Flowerless plants (such as the Ferns), in most cases speedily ceases to grow, and the efficient roots are really lateral organs. Where the primary radicle is developed, we have a true root (fig. 5); but the roots which are produced from the *sides* of stems, or from leaves, are termed *adventitious* roots (fig. 4).

Fig. 5.



Root of the Mallow (*Malva rotundifolia*).

The axial root may be seen well in any seedling Dicotyledonous plant, as in a young Bean or Turnip; and by watching the germination of a few seeds of such plants, the development of the radicle into the axial root may be readily traced. The axial nature of the root is clearly evident in the full-grown plants of most annual garden species of Dicotyledons; and in shrubby and arborescent perennials of this class the axial root is persistent, growing by annual increase into a large woody mass, proportionate to that of the ascending stem or trunk.

The origin of *adventitious* roots may be germinating seeds

of Monocotyledonous plants, such as grains of Oats, Wheat, &c.; but their essential character may be still more clearly distinguished in plants which form adventitious roots on well-developed stems and bud-like structures. The fibrils which sprout from the joints of the stems of numerous creeping plants (Ground-Ivy, Mint, Sand-Sedge, &c.), the clamping roots of Ivy-stems, the roots of an Onion-bulb, as well as those formed from slips or cuttings, &c., afford familiar examples of adventitious roots.

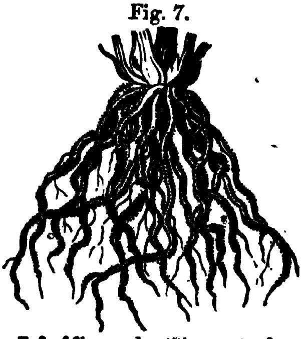
Fig. 6.

Fusiform tap-root of the Carrot (*Daucus Carota*).

Ramification.—Where the branches of the root are comparatively small and the central axis is both thick and considerably elongated, the root is called a *tap-root* (fig. 6); where the branches are developed so that the principal axis is lost as it were in its own ramifications, the root is called *fibrous* (fig. 5). The branches issue from the main root in succession from above downwards (not from below upwards as in stems), and are, in the first instance, regularly arranged in rows one above another. The number of rows varies in different cases; and the regularity of disposition is soon lost.

When the tap-root exists in herbaceous plants, it often exhibits a more or less succulent character, and becomes a *tuberous root*, as in the biennial Turnip, Carrot, Beet, &c., where this organ is peculiarly developed in the first season of growth, to serve as a reservoir of nutriment. The tendency of such plants to exhibit this character in excess under the influence of stimuli renders them extremely valuable for economic purposes. The fibrous rootlets upon the surface of tuberous tap-roots, like the Carrot, Parsnep, &c., appear to be mostly true roots. A distinction is made, in describing tuberous roots, between those which are *fusiform*, as in the Carrot, and those which are *napiform*, as in the Turnip. A woody tap-root is found in many forest-trees, as, for example, in the Oak; but here the branches share more extensively in the increase in size, and their direction tends more to the horizontal. Fibrous roots are particularly characteristic of plants growing in light and sandy soils or in water; the perennial, woody forms are especially characteristic of shrubby Dicotyledons.

Fig. 7.



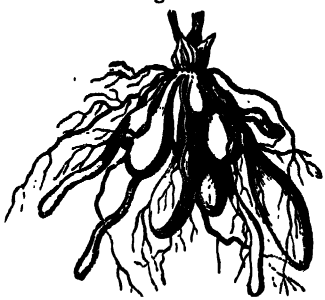
Tuft of fibrous adventitious roots of a Grass.

In general terms it may be stated that the form assumed by the roots, whether true or adventitious, is in direct relation to the nature of the medium in which they grow and the purposes they have to serve as feeding roots, hold-fasts, or reservoirs of nutriment.

Adventitious Roots (figs. 4, 7) are sp
by no means confined to, Monocotyledons and Flowerless plants, since their radicles are usually arrested in their growth; they are also necessarily the only kind which can occur upon specimens of Dicotyledonous plants which have been raised, not from seeds, but from cuttings, layers, tubers, &c. They arise from the *side* of the stem which gives birth to them, and most readily in the vicinity of buds or leaves.

Adventitious roots are very variable in form and consistence. They may be fibrous (fig. 7) or tuberous (fig. 8), and are not uncommonly of intermediate character in the Monocotyledons, consisting of more or less thick fleshy fibres. Either the fibrous or tuberous form may occur exclusively in groups of adventitious roots, or such groups may contain roots or rootlets of both kinds. In arborescent Monocotyledons the adventitious roots acquire a woody character and great size; in herbaceous Monocotyledons they are commonly annual, or, if tuberous, biennial.

Fig. 8.



Fasciculate adventitious roots of *Ranunculus Ficaria*, partly fibrous, partly tuberous.

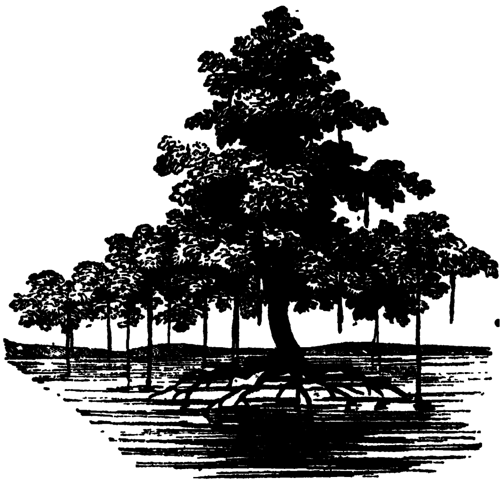
The *fibrous* adventitious roots of Monocotyledons are generally soft, much elongated, and little divided, like those at the base of bulbs of the Hyacinth, Onion, &c. (fig. 17). A mixture of fibrous and tuberous adventitious roots, forming what is called a *fasciculate* root, occurs in *Hemerocallis*, and in *Ranunculus Ficaria* (fig. 8), in which, as in the plant last mentioned, the structure is still further complicated by the existence of buds, as explained further on under the head of Tubers. A peculiar modification of this structure is found also in most terrestrial Orchids. In *Spiræa filipendula* the fibrous roots exhibit tuberous thickenings at intervals.

Root-hairs.—The youngest parts of rootlets, whether branches of axial roots or adventitious roots, often exhibit a coat of delicate cottony *root-hairs*, which are thread-like growths from the epidermis (*trichomes*), and are thrown off in perennial roots when the epidermis gives place to the rind.

The nature of the root-hairs will be explained under the head of the Anatomy of Roots. Examples may be found in seedling plants of mustard, in potted Geraniums (*Pelargonium*), or in the roots of many Monocotyledonous bulbous plants and Grasses growing in damp places.

Media in which Roots grow.—Roots of ordinary plants bury themselves in the soil; those of water-plants, usually more succulent in their texture, penetrate the mud, as in the Water-lilies, or hang freely down in the water, as in Duckweed and the Water Crowfoot. A number of plants exhibit what are called *aërial* roots, which are always adventitious; and these may be either the

Fig. 9.



Sketch of a Mangrove-tree (*Rhizophora*), with true roots descending from the branches.

sole radical organs of the plant, or roots developed high above the ground but growing down to reach the soil, or they may be converted into organs of support for a weak stem. In true parasitical plants, like the Mistletoe, the roots, more or less developed, attach themselves to, and become organically blended with, the roots or stems of other plants.

The plants called *epiphytes*, such as the aërial Orchids, various Araceous plants, and members of the Pine-apple family, are possessed of aërial roots alone. The stem of such plants rests upon some foreign body, such as the branch of a tree, totally unconnected with the earth, and produces long adventitious roots which hang suspended in the atmosphere. Roots

developed in the air, and subsequently descending, present themselves in various conditions. One of the most remarkable is that which is observed in the Mangroves (fig. 9) (Rhizophoraceæ), where the seed germinates in the fruit while the latter is still attached to the tree, and drops down its long radicle until it reaches the mud in which these trees grow, so that the stem of the young plant is enabled to establish itself firmly in the uncertain soil before it detaches itself from the parent. This is an axial root. In the Banyan tree (*Ficus indica*) adventitious roots are frequently developed on the branches, which, descending to the earth, pene-

Fig. 10.

Pandanus odoratissimus, the Screw-pine, with adventitious roots supporting the trunk.

trate into it and become supporting columns, which ultimately assume the appearance of trunks, and give the tree the appearance of a group or even a grove of trees united together at their heads. The roots of the arborescent Monocotyledons partake to a certain extent of the same character; and those of Palm-trees are observed to arise successively one above another in a spiral course near the base of the stem, growing outwards and downwards to penetrate the ground, the older ones ultimately decaying. In the Screw-pines (*Pandanus*, fig. 10) this is still more striking and distinct, as the spiral line which they form is more open,

and the roots arise a long way up the stem; here also the older roots and the base of the stem decay, so that the whole plant comes to be supported by the lateral adventitious roots, as on so many props. Aërial roots becoming organs of attachment may be seen in the climbing stems of Ivy, of the garden Bignonia (*Tecoma radicans*), &c.

Parasitic Plants developed from seeds present, in their earliest stages, a radicle which in some cases becomes developed, in others not, or only in a peculiar manner. Some germinate in the usual way, in the earth, and their roots seek out those of their proper nurse plants, to which they attach themselves organically, others superficially or by penetrating deeply into the interior; in such cases they may be wholly parasitic, as in the leafless Broom-rapes (*Orobanchaceæ*), or only partly dependent, as in *Thesium*, *Rhinanthus*, and *Melampyrum*. Others germinate in the usual way in the soil; but their young stems attach themselves to those of other plants by adventitious roots developed at the points of contact, while the lower part of the parasite, connected with the ground, soon dies away, as in the Dodder (*Cuscuta*). The woody parasites, Mistletoe (*Viscum*), *Myzodendron*, and others, are developed from seed upon the spot where they are attached. In the Mistletoe, the seed clings by its viscid pulp; in *Myzodendron* by coiled hairy arms; and when the radicle sprouts, it drives its way through the rind of the nurse plant until it reaches the cambium layer, where it connects itself organically, becoming grafted exactly like a budded rose. No further development of root-structure occurring here, the full-grown plant appears rootless, and like a branch or graft upon the nurse tree. The earlier stages of growth of the Rhizantheæ, root-parasites composed chiefly of inflorescence, are not known; probably they are analogous to those of *Viscum* in the first instance, but with the addition of horizontal growths of stem-structure beneath the bark of the nurse plant.

Characters presented by the Root, &c.—The points to be specially attended to in studying and describing the root, such as the form, ramification, &c., may be gleaned from what has been before stated and from the Section on the Description of Plants.

Sect. 3. The Stem.

Definition.—The stem is the ascending portion of the axis of a plant. It is usually characterized by its growth taking place in a direction contrary to that of the roots, and by bearing on its sides regularly arranged leaves or modifications of leaves, forming the *lateral* or *appendicular organs*. The term *caulome* is applied in a comprehensive sense to any stem or branch or to any modification of those organs bearing leaves or modified leaves, *phyllomes*.

Exceptions.—An exception to the ascending growth occurs in the case of creeping stems, where the main axis takes a more or less horizontal position; but the first shoots of such plants, developed from their seeds, ascend, and the secondary axes, which bear the efficient leaves, assume the

erect position, as is seen in the tufted habit of growth of plants with a subterraneous main stem. (See also p. 15.)

Buds.—Every stem is developed from a *bud*, which consists of a conical rudiment or growing-point of the stem bearing rudimentary leaves crowded upon its sides. The primary bud of the stem of Flowering plants presents itself as the *plumule* (fig. 3) of the embryo; and so long as this axis continues to grow, a bud (the *terminal bud*) is found at its extremity. The branching of a stem depends upon the development of lateral buds, which, as a general rule, appear only in the *axil* or upper angle between the base of a leaf and the stem, whence they are called *axillary buds.*

There is in many embryo plants a small portion of the axis intermediate in structure as in position between the true root and the true stem (fig. 3). This "*hypocotyledonary axis*" or *tigellum* sometimes gives off shoots, by which it may be distinguished from roots; moreover it is either cylindrical or tapers upwards, while a root tapers in the opposite direction. This hypocotyledonary axis forms the trunk of the extraordinary plant called *Welwitschia*, hereafter described.

Nodes and Internodes. — The place whence a leaf arises marks the position of a structural region endowed with special physiological activity; it defines externally a point where the internal tissues have a peculiar arrangement. Hence a particular name is applied to it, that of *node*. Sometimes a kind of articulation of the stem occurs at this point, but not as a general rule. The intervals between the points of origin of leaves are called the *internodes.* In buds, the internodes are not yet developed. In a large majority of ascending stems the internodes become considerably developed, so that the leaves ultimately appear stationed at distinct intervals. In many subterranean stems, at the lower part of the stems of many herbaceous plants (fig. 11), and in the trunks of many of the arborescent Monocotyledons, the internodes never become much lengthened, and the leaves in consequence appear

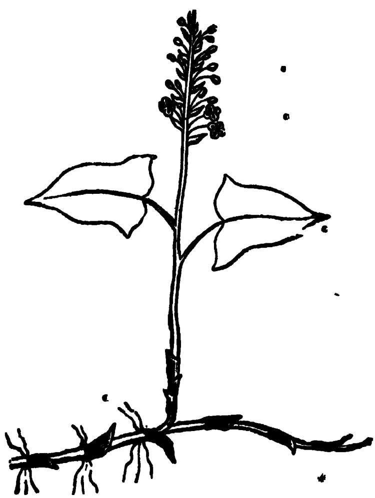
Fig. 11.

Diagram of *Plantago media* bearing leaves crowded on a stem with undeveloped internodes. The short stem seen in section.

closely packed and more or less overlapping in the full-grown plants. Such plants are sometimes, but erroneously, called *acaulescent* or stemless plants.

The relative development of the internodes is next in importance to the order of arrangement of the axillary buds in affecting the general forms of stems. A clear idea of the conditions may be obtained by examining, in the first instance, what occurs in the unfolding of the bud of such a tree as the Horse-chestnut. In the bud the enveloping scales, the rudimentary leaves, and even the blossom may be distinguished, crowded on the undeveloped axis. As the leaves emerge and expand, they become separated from each other by the elongation of the internodes of the stem, until at length they stand at considerable distances along the sides of a shoot several feet long. This may be illustrated by comparing it to the separation of the joints of a telescope, when its lengths of tubes are successively pulled out. Examples of permanently *undeveloped internodes* are seen in the rosette-like offshoots of House-leeks and of many other herbaceous perennials—in the first season's growth of such plants as the Turnip, Carrot, Canterbury-bell, and indeed of most biennials, where the leaves all appear to arise from the root—in the bulbs of many Monocotyledons, such as the Crocus, Hyacinth (fig. 17), &c. In these cases the flowering axis which subsequently appears often develops its internodes considerably, and rises as a tall stem. An intermediate condition is met with in stems which are elongated, but have the leaves closely overlapping, as in the common Stonecrop, many Coniferous trees, many Palms (fig. 33), &c.; and a similar condition exists in the subterraneous root-stocks of various plants, where the imperfect sheathing leaf-scales succeed each other at short intervals.

Fig. 12.



A plant of *Smilacina bifolia* with a creeping rhizome bearing *leaf-scales*, an erect *leafy* stem, and an inflorescence with *bracts*.

Regions of the Stem.—In the embryo of a Flowering plant it is scarcely possible to define the limits even of the stem itself, which loses itself above in the plumule, and below in the radicle. But in fully-developed stems, a general division into three regions may be distinguished, according to the kind of lateral organs which they bear, viz:—

1. The *Leaf-scale* region (fig. 12), which is mostly subterranean

in its habit, and presents itself with more or less of the external appearance of a root, of an enlarged fleshy bud, or of a combination of these two. The leaves upon this are never green, but are of fleshy or membranous texture and simple forms. Leaves of this character are found on the outside of buds.

2. The *Leaf* region, forming the ascending stem of plants generally, especially characterized by the green colour and great development of the foliage.

3. The *Bract* region, which is also known as the *Inflorescence*, is distinguished by its smaller, more delicate, and sometimes coloured leaves, the axillary buds of which produce flowers.

The extent, both positive and relative, in which these regions are represented is different in almost every plant; but a few general statements may be made serving to illustrate the subject. The leaf-scale region is developed chiefly in *herbaceous perennial* plants; and the principal modifications of it will be examined below under the heads of Rhizomes, Bulbs, and allied structures. It may be observed that the leaf-scales or abortive

Fig. 13.

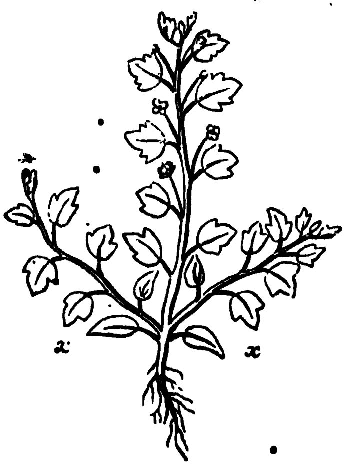


Diagram of a plant of *Veronica hederæfolia*, where the leaf-scale region bears the cotyledons *x*, *x*, and the rest of the stem is a true-leaf stem with flowers in the axils of its upper leaves.

Fig. 14.

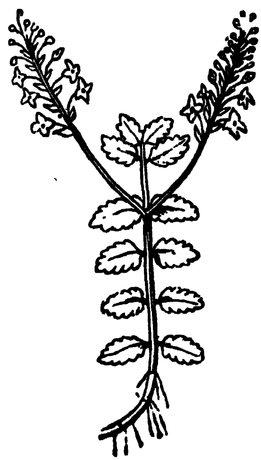


Diagram of a plant of *Veronica Chamædrys*. The lower part is a true-leaf stem, and its branches are bract-stems or inflorescences. The roots proceeding from the stem are adventitious.

foliaceous organs are almost exclusively composed of the stalks or sheaths of leaves, without any part corresponding to the blade; exceptions to this, illustrating the rule, occur in tunicated bulbs like the Hyacinth

(fig. 17), where the inner scales bear a green blade standing out free at the top of the bulb, and again in various subaquatic Grasses with creeping stems, in which the lower parts of the annual shoots often exhibit large open sheaths with small rudiments of blade at their summits. The region bearing perfect leaves forms the principal part of the axis in arborescent plants, where the leaf-scale region occurs only at the points where the protecting scales of the autumn buds are produced. The scars of the leaf-series, crowded together from the non-devělopment of the internodes, are very visible at the base of the yearly shoots of many trees, for example, of the Horse-chestnut: other trees reproduce, as it were, their cotyledons at these points; the Jasmine, for example, exhibits a pair of broad undivided leaves near the base of each annual shoot. In annual plants the leaf-region is predominant, but the bract-region is relatively more developed than in trees; and the same holds good of perennial herbaceous plants. In arborescent plants the bract-region usually does not present itself until the leaf-regions of many years have been formed, and even then it is generally formed from branches of the axis which have a subordinate share in giving the special form to the entire plant; sometimes, however, the form of the ramification is much affected by the position of this region, as in the Horse-chestnut, Lilac, and other trees, where the terminal buds of shoots are developed into an inflorescence, which of course puts a stop to the onward growth at these points.

Fig. 15.

Diagram of a plant of *Ophrys arachnites*. The leaf-scale, true-leaf, and bract regions successively presented in the same axis.

Leaf-scale Region.—The leaf-scaled stem, found especially among *herbaceous perennial* plants, or such as live for several years without forming a permanent woody stem above ground, is seldom continuous with an axial root; on the other hand, it is very prone to produce adventitious roots, as is natural to its usually subterranean or creeping mode of growth. When its internodes are regularly although slightly developed year after year, it forms an abbreviated stem, horizontal or ascending, either below or above ground. If the main axis persists, producing a few branches each year, and as it grows at one end slowly dies away at the other, a more or less root-like structure is produced, termed a *root-stock* or *rhizome* (fig. 12). If the growth of each axis decays away at regular intervals, so as to isolate the products of the succeeding axes, the result is different, and, instead of a branching rhizome, the axis resolves itself into a number of detached portions, in the form of *corms*. If these detached portions are chiefly composed of leaf-scales, with the undeveloped stem small, so that they represent enlarged buds, they are called *bulbs* (figs. 16 & 17). Another re-

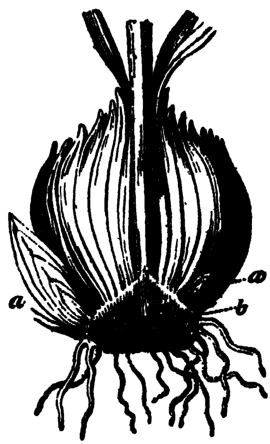
productive structure belonging to the leaf-scale region of the stem is the *tuber* (fig. 19), which consists of a fleshy thickened subterranean axis, arising in the axil of a leaf-scale, having its own internodes considerably developed, so that its leaf-scales are scattered and cover isolated buds or "eyes." Tubers of analogous character are sometimes formed from aërial branches, as in many epiphytic Orchids, where they have a green colour and are known as *pseudo-bulbs*.

Bulb.—The bulb (fig. 16) is a stem remaining permanently in the condition of a bud. Its axis consists of a disk or short conical plate, from the upper surface of which arise leaf-scales of fleshy character more or less overlapping each other and enclosing the points of growth, while one or more circles of adventitious roots are given off from the base (fig. 17). Bulbs are named, ac-

Fig. 16.

Scaly bulb of *Lilium candidum*, with adventitious roots.

Fig. 17.



Tunicated bulb of the Garden Hyacinth, cut through perpendicularly, showing the leaf-scales arising from the abbreviated stem (*b*), and the young bulbils or cloves (*a*, *a*) formed in the axils of leaf-scales.

cording to the character of their leaf-scales, *scaly* or *squamose* when these only partially overlap (Lily), and *tunicated* when the scales form complete sheaths (Onion, Hyacinth). Bulbs produce flowering axes either from the terminal or from axillary buds. They are multiplied by buds developed in the axils of the scales in the form of new bulbs (fig. 17, *a*, *a*), which sooner or later become detached.

When a bulb flowers from its terminal bud in its first season of growth, it is *annual*; when it only strengthens itself by forming scales in the first season, and flowers from the terminal bud in the second, it is *biennial*; when it flowers from an axillary bud, the terminal bud may be developed in the same form indefinitely and form a *perennial* bulb.

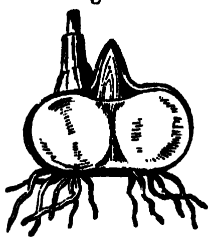
The number of leaf-scales constituting the mass of a bulb varies much in different plants: in *Gagea* and others there exists only one; *Allium oleraceum* has but two; the Garden Tulip and Crown Imperial have comparatively few scales, while the Lilies and the Hyacinth (figs. 16 & 17) have numerous coats or scales. A little explanation is requisite as to the terms *annual* &c. as applied to bulbs. We have an example of what is called an annual bulb in the Garden Tulip. As planted in autumn, it is a bud composed of four or five scales enveloping a central rudimentary flowering stem which terminates the main axis. In the axil of the outer scale there is an axillary bud. As the flowering stem is developed the old bulb shrinks, while the axillary bud becomes more and more perfect; so that, after the flowering season is over, it forms a new bulb, to the side of which the withered remains of the old one are attached. The terminal point of the new bud repeats the flowering, and its outer scale (sometimes the next also) subtends an axillary bud destined to become a new bulb in the next season. Such bulbs are sometimes called *præventitious*, since the bulbous structure of any given axis is formed before the true leaves and flower. The Crown Imperial (*Fritilaria imperialis*) affords an example of a *biennial* bulb. Examined in the autumn, it is found to consist of fleshy scales produced at the lower part of the axis which has just flowered; while a bud seated in the axil of the innermost of these scales is already developed, and by the decay of the old flowering stem has come to occupy the centre of the bulb. In the next season this bud flowers: at first it is surrounded by the scales of its parent axis; but after the flowering is over, these very quickly shrivel up and disappear, the axis which has just flowered giving origin at its base to a number of scales replacing them; and while the flowering stem decays away down to these scales, a new axillary bud is developed in the axil of its innermost or uppermost basal scale. Thus the bulb always bears growths belonging to two seasons on the same axis: the nutrient leaf-scales of each axis are developed upon it *after* it has flowered, and serve for the support of the flower of the next axis. Such bulbs are sometimes called *postventitious*, and may be termed *definite* to distinguish them from the next kind. *Perennial* bulbs differ from the foregoing in retaining the products of the condensed axes of several years in a healthy vegetative condition. Thus, if we examine a bulb of the Garden Hyacinth (fig. 17) when it is flowering by its terminal bud, we find the base of the flowering axis surrounded by several leaves belonging to itself; the whole of them stand in the axil of a scale belonging to the preceding year, which also contains the short remnant of the flower-stalk of that year; and to this scale succeed several more, all belonging to that same axis; these moreover stand collectively in the axil of the innermost of a series of scales belonging to the year before, remains of the flower-stalk of which are

also sometimes visible. Finally, on examining the axil of the innermost green leaf of the present year, we find, nestled between it and the base of the flower-stalk, the bud which is to form the axis of the next year. Therefore this bulb possesses structures or axes belonging to four distinct generations. The bases of the green leaves expand into fleshy sheathing coats after the flowering of the axis which gives rise to them; and the decay of their blades, which extends to the summit of the bulb, gives rise to the ragged or bitten-off appearance of the latter. These bulbs are *postventitious* like the last kind, but may be distinguished from them as *indefinite*.

Corm.—The corm more or less resembles a bulb externally, but consists principally of a stem with little-developed internodes, thickened into a fleshy body, and bearing leaf-buds at one point, either at the summit, as in the Crocus (fig. 18), or at the side, as in *Colchicum*.

The corm of a Crocus examined very early in spring exhibits a primary axis in the form of a roundish mass bearing the adventitious roots below, and giving rise above to one or several tufts of leaves. The bases of the leaves, outside which are a few membranous scales, being at first sunk in the parent axis, these tufts or rudimentary branches are not readily distinguished as secondary axes; but the terminal bud soon grows out to produce the flower. After the flowering is over, the internodes between the scales and the bases of the green leaves become developed both vertically and also horizontally, so as to convert the base of each flowering stem into a new corm. When about half-grown the new corms stand out as globular bud-like structures on the top of the old corm, which is gradually exhausted, and decays away, so as to set its progeny free. In the axils of the uppermost leaves of the flowering stem are developed new buds (which exist even before the corm begins to sprout in spring); and as the new corms are perfected, the buds imbedded in their summits form the rudiments of the leaves and flowers of the next season, sprouting out in the spring, each to reproduce a corm. Hence in a corm taken out of the ground a short time after the flower withers, we find three sets of axes:—1, the withering parent corm; 2, the young corms branching from this, formed from the bases of the flowering stems; and, 3, the axillary buds of the leaves of the latter, forming the resting buds at the summits of the new corms.

Fig. 18.



Corm of the Garden Crocus, cut through perpendicularly.

In *Colchicum autumnale* the conditions are somewhat different. When the plant is flowering, in autumn, we find the flowering stem attached to the side of the base of the corm; the flowering stem is surrounded at its base by sheathing scales and rudimentary leaves; in the axils of the two lowest leaves exist minute buds, and the internodes between these leaves are slightly developed. The flowering stem then withers down to the ground, and during the winter the internode between the two buds swells

and forms a new corm, the old one shrivelling up. The leaves appear above ground in the spring, proceeding from the apex of the corm, and the bud at the side of its lower end shoots out to form a new lateral stem, which produces sheaths and rudimentary leaves, and ultimately forms the flowering stem of the next autumn, the base of which repeats the formation of a corm in like manner and shoots up its tuft of leaves in the following spring. The corm being formed from the internode between the buds, the lower of these is, to a certain extent, basilar as well as lateral, while the upper one appears near the top of the perfect corm, rather to one side, near the scar of the old leaves and flower-stalk: this bud may or may not be developed into a corm simultaneously; but in any case it becomes detached from its fellow when the old corm shrivels up, and thus may multiply the plant.

The corm of *Arum maculatum*, examined in spring, exhibits two lobes, with an intermediate constriction; they lie adjoined horizontally: the corm of the past year is shrivelled; the other is solid, and at the summit exhibits sheathing scales enveloping the base of the erect flowering stem. Opening the sheath, which turns upward, we see that the flower arises from a terminal bud, while in the axil of a leaf arising below it exists a bud which is destined to swell up and form a new corm for the next season, the oldest one meantime withering away; so that two generations with the rudiments of the third always coexist; these generations may consist of a greater number of individuals when additional corms arise from the axils of several of the scales of the parent corm.

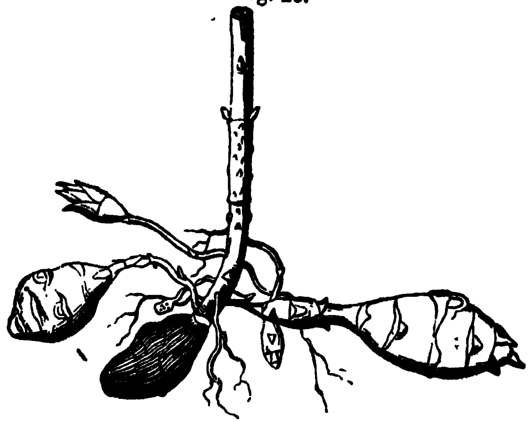
Tubers.—The stem-tuber is either formed from the base of a stem, or from a branch arising from a subterraneous leaf-scale (fig. 20), developed either partially or entirely into a thick and fleshy mass, by expansion of its spongy structure, its own leaves appearing in the form of rudimentary scales, in the axils of which exist dormant buds, or eyes, capable of producing independent stems when the tuber recommences its development after a season of rest.

Fig. 19.

Tuber formed at the base of the stem of *Bunium Bulbocastanum*.

Axial tubers occur in many herbaceous plants, as in *Corydalis bulbosa*; when of annual duration, these are essentially the same as corms. The tuber of the Potato is a familiar example of the stem-tuber formed from a branch, in which its characters may be readily observed; a number of leaf-scales at the base of the "haulm" send out subterraneous branches, which at some distance from the point of origin cease to elongate, and swell up into tuberous masses. The tubers of the Jerusalem Artichoke (fig. 20) are analogous productions. Stem-tubers passing more or less into rhizomes form the so-called roots of the Bryonies (*Tamus communis* and *Bryonia dioica*), of the Sweet-potato (*Convolvulus Batatas*), and the

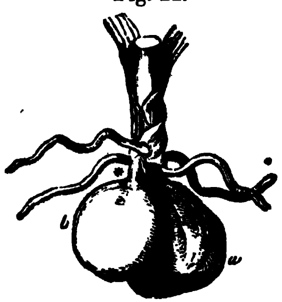
Fig. 20.



Stem-tubers of the Jerusalem Artichoke (*Helianthus tuberosus*).

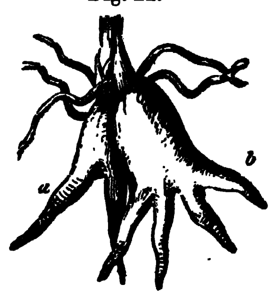
species of *Dioscorea* yielding "yams." The tubers of the terrestrial Orchids are chiefly composed of radical structures. If we examine the twin tubers of *Orchis Morio* (fig. 21), we find one at the base of the flowering stem (*a*), which towards the close of the season is withered, while the other (*b*), crowned by a bud (*), is solid and healthy: in the axil of the lowest leaf of this bud exists another bud in a rudimentary state; and as the oldest tuber shrivels, this swells out and assumes its form, in the next season appearing as the bud-tuber, while its parent becomes the tuber of the flowering stem. The greatest part of the mass of these tubers consists of a swollen adventitious root, which is intimately blended with a few little-developed stem-internodes and the

Fig. 21.



Double root-tubers of *Orchis Morio*: *a*, old tuber; *b*, new tuber with the bud * for the next season.

Fig. 22.



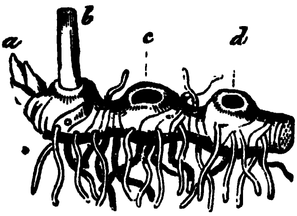
Double palmate root-tubers of *Gymnadenia odoratissima*: *a*, old tuber at the base of the old flower-stem; *b*, new tuber, with bud for the next season.

terminal bud. In some cases these tubers are rounded; in others they are divided below, so as to become *palmate* (fig. 22). The tubers of *Bunium* (fig. 19) belong to the root.

Rhizome.—The rhizome or root-stock is a body composed of an indefinite number of corm-like axes permanently connected together, so as to form an elongated, root-like stem, more or less clothed with leaf-scales (fig. 23). Its internodes are generally little developed; sometimes, however, regions with developed internodes alternate with others wherein they are undeveloped, giving a nodose character; when it has the internodes much developed (figs. 12 & 25), it approaches in character (through "runners" &c.) to creeping leafy stems. Its texture and appearance vary from herbaceous or fibrous (fig. 25) to tuberous (fig. 23); its direction is usually horizontal, though in some cases it is vertical (fig. 24); and in the majority of cases it grows under ground.

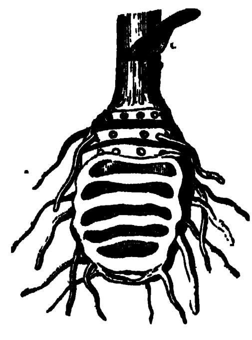
Examples of the rhizome are very numerous among herbaceous perennial plants, both Dicotyledons and Monocotyledons. The Iris affords an example of a tuberous rhizome which may be understood by comparing it with a corm like that of *Arum maculatum*, and by supposing that the older portions of this survive for many years, so as to form a creeping, more or less branched mass. The Solomon's Seal (fig. 23), Sweet-flag (*Acorus*), Ginger, Water-lily, &c. afford other well-known examples.

Fig. 23.



Rhizome of Solomon's Seal (*Convallaria polygonatum*): *a*, bud for next year; *b*, flowering stem of the present year; *c* & *d*, scars of the flowering stems of two preceding years.

Fig. 24.



Vertical rhizome of *Cicuta virosa*, cut through perpendicularly.

In some of these (called *definite rhizomes*) the flowers appear to be produced by terminal buds, which take an ascending direction and lose themselves in the inflorescence, the onward growth of the stem being effected by means of axillary buds. In others (*indefinite rhizomes*) the growth is continuous by the formation year after year of a terminal leaf-bud. Rhizomes of more solid texture, but of analogous construction, occur in many Ferns, as in *Aspidium Filix-mas*, also in most of the Rushes

(*Juncus*), and a great variety of herbaceous Dicotyledons, such as the Primrose, &c. Certain widely extending creeping plants afford examples of rhizomes with developed internodes, as the Sand-Sedge (fig. 25), the wire-like rhizome of which extends for many yards under the loose sand, sending up leafy shoots at regular intervals; the stems of Couch-grass, of various Mints, and other Labiate plants; as also of certain Ferns, such as *Lastræa Thelypteris*, and of the Horsetails (*Equisetum*), &c. When the rhizome is erect it has much of the aspect of a root; and the ordinary form was termed by the old writers a *premorse* root, the decay of the lower end giving it the appearance of having been gnawed off. Examples of this are not uncommon, as in the *Scabiosa succisa*—in various Umbelliferæ, as *Cicuta virosa* (fig. 24), where the abbreviated internodes form discoid chambers corresponding with the fistular internodes above, and in the Lady-fern (*Athyrium Filix-fœmina*), which consequently rises above ground like a dwarf tree-fern. In *Sparganium ramosum* we meet with a curious alternation of condensed and elongated internodes, so that the rhizomes appear to consist of a number of corms connected together by branches into an erect candelabrum-like assemblage.

Fig. 25.

Sand-Sedge (*Carex arenaria*), the creeping fibrous rhizomes rooting at the nodes and sending up flowering stems.

The true-leaf Region.—The leafy stem, or region bearing green foliaceous organs, grows above the soil, either in air or water, exposed to the influence of light. Its form and structure are extremely varied, depending chiefly on the mode of development of the internodes, the arrangement of the leaves and mode of development of the buds, and the extent to which its existence is prolonged. The first cause regulates to a great extent the form of the axis, the second the mode of ramification, and the third the size and consistence of the full-grown organ. The principal modifications may be most conveniently studied under the heads of—1. *herbaceous*, and 2. *woody* stems.

Herbaceous stems, or such as do not become woody, but die down to the ground in winter, are produced by annual and biennial plants, and in each successive flowering axis of herbaceous perennials; to these also are analogous the yearling shoots of arborescent plants. Taken by themselves, they are either *annual* or *biennial*; that is to say, they bear on the same axis green leaves belonging either only to one or to two seasons of growth. Annual herbaceous stems alone, of course, occur on true annual plants: they are produced also by those perennial herbaceous plants which send up a flowering stem from beneath the soil in spring; and with these are to be included most plants forming bulbs and corms.

In ordinary annuals the plumule or terminal bud of the seed shoots up at once into a more or less branched flowering stem, and the entire plant dies away after the seeds are perfected in autumn. Examples of this form may be seen in the Sweet Pea, *Veronica hederæfolia* (fig. 13), &c. In many perennial herbaceous plants forming rhizomes, and in most bulbous plants, a subterraneous bud shoots up in the early part of each season of growth, bearing green leaves and forming a flowering stem (fig. 23, *b*); in the autumn the whole of these structures disappear (*c*, *d*), while resting buds (*a*) are formed in the axils of the lower leaves beneath the soil, to repeat the growth in the following season. We have examples of this kind of stem in the Solomon's Seal, Garden Pæony, Aconite, Asparagus, &c. The young fleshy shoot with rudimentary leaves which these plants form in early spring is sometimes called a *turio* (this is exemplified in the edible part of the Asparagus). The leafy flowering stems of bulbs and tubers, such as those of the Lily, Potato, *Orchis*, &c., furnish further examples of the annual herbaceous stem.

Biennial herbaceous stems are found in true biennials and many herbaceous perennials. They are distinguished by the lower part of the axis producing green leaves in one season, and the upper portion growing into a flowering stem in the following year. Generally speaking, the internodes are little developed in the growth of the first season, and the leaves are often larger as well as more crowded; they also frequently die away early in the second season.

Examples of the biennial herbaceous stem are o be found in such true biennial plants as the Turnip, the Thistle, Parsley, &c. Here, when the seed is sown, it produces a stem with scarcely developed internodes, supporting a number of leaves which form a kind of tuft or rosette upon the ground; this growth remains almost at rest during the winter, and in the succeeding spring the terminal bud shoots up into a flowering stem. Sometimes several axillary buds also grow up into flowering stems, giving rise to the condition called "*radix multiceps*:" this may occur either in biennials or perennials. A similar kind of stem is found in such perennial herbaceous plants as the common Daisy, the Dandelion, &c.,

where axillary buds are produced at the base of the dying flowering stem in autumn, and grow up above ground at once to form leafy tufts, lasting through the winter, and giving birth to flowering stems in the next season.

Offsets, Runners, etc.—The leafy shoots of perennial plants, with their axis and adventitious roots, may be separated artificially, and used for propagating the plant (gardeners call this "parting the roots"); and certain plants are naturally multiplied in the same way, by buds or branches which have received special names. Thus the herbaceous flowering stems of the House-leeks (*Sempervivum*), after flowering, produce buds in the axils of their lower leaves which expand into leafy rosettes. The parent stem dying down, these are thrown off as detached plants, and strike root; in the following season they send up a flowering stalk and repeat the process. The separating tuft formed in the autumn is called an *offset* or *stolon*. The Strawberry-plant in like manner produces, in the axils of its leaves, buds which in the same season expand several of their internodes, and form long filiform branches, the buds of which give rise to rosettes of leaves, and strike root, and

Fig. 26.

Strawberry-plant with runners.

thus form independent plants: such shoots are called *runners* (fig. 26). In all these cases the herbaceous flowering stem is of two years' growth, its branching portion belonging to the autumn, the ascending flowering portion to the succeeding spring or summer.

Special names have been given to certain forms of the herbaceous stems, some of which are not very definite. Botanists sometimes call the stem of Grasses a *culm*.

Woody Stem. Buds.—The stem characteristic of arborescent plants presents itself in two principal classes of form:—one, where it is branched, constituting a *trunk* (*truncus*); the other, where it is an unbranched column, bearing its foliage as a terminal crown, forming what is sometimes called a *stock* (*caudex*).

These differences depend upon the number, position, and mode of development of the buds, only a few of which, in most cases, lengthen into shoots, the others becoming arrested in their growth. When, as in Dicotyledonous trees generally, *axillary buds*, or those formed on the side of the stem in the *axils*, or point of junction of the leaf with the stem, are developed into branches, we find a ramified trunk; when the terminal bud alone unfolds, as in most Palms, the globular and columnar Cactaceæ, and the Cycadaceæ, a simple columnar caudex is formed.

It is evident from this, that the mode of branching of a stem must be essentially dependent on the arrangement of leaves; but a complication arises from the frequent suppression or non-development of the axillary buds, often according to a regular plan; and, in fact, it is very seldom that all the axillary buds of a stem are developed (figs. 27 & 28).

Fig. 27.

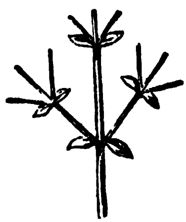


Fig. 28.

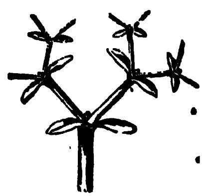


Fig. 27. Plan of indefinite ramification, with development of terminal and axillary shoots.
Fig. 28. Plan of definite ramification, with arrest of the terminal and development of the axillary buds, producing bifurcation.

This abortion of axillary buds is most extensively displayed in Monocotyledons; for the frequent existence of dormant buds in the leaf-axils, even of Palms, is shown not only by the occasional production of isolated lateral shoots, but by the frequent, and in some cases constant, development of buds in the axils of the basilar leaves, forming suckers round the base of the stem. A similar phenomenon occurs in the propagation of *bulbs*, &c.

Among Dicotyledonous plants, the influence of the suppression of buds in regular order is very great. In the Labiatæ we have opposite leaves; and as pairs of axillary buds are developed, the ramification is generally very symmetrical; in some of the *Caryophyllaceæ* with similarly *decussate* opposite leaves, one axillary bud only is developed, and the other is suppressed at each node, so that the branches, arising one by one, stand spirally arranged upon the stem. In the Firs, the branches often appear to arise in whorls, owing to the periodical development of a number of buds in the axils of closely succeeding spirally arranged leaves, with long intervals of total abortion.

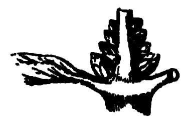
Some trees grow year after year from the terminal bud, which closes up into a winter-bud in autumn (fig. 30). In the Elm &c. the terminal bud is not developed in the autumn, and the axillary bud next below continues the growth. In the Horse-chestnut the terminal bud of the annual shoot resolves itself into an inflorescence, and the growth of the next year depends upon the axillary buds; the same is the case in the Lilac (*Syringa vulgaris*) (fig. 29), in which, however, in this country, the terminal bud is generally abortive or suppressed, and the pair of axillary buds next below produce blossom, causing still more marked bifurcation of the branches.

Fig. 29. Fig. 30.

Fig. 29. Shoot of the Lilac, destroyed down to the first pair of axillary buds.
Fig. 30. A shoot, with a terminal (*a*) and solitary axillary buds (*b*, *b*, *b*).

As a general rule, of course, the frequent suppression or conversion into blossom of terminal buds tends to produce a bushy mode of growth, and *vice versâ*. In addition to this, the relative *force* of development of terminal and axillary buds is very important in determining general form, as we see in comparing the Black Poplar with its common tall variety the Lombardy Poplar, or Coniferous trees generally with deciduous trees. Even among the individuals of the same species we observe great differences in this respect, dependent on external conditions; for both Dicotyledonous trees and Conifers differ much in the relative proportion of main trunk and branches, when grown in close plantations, or standing in open situations.

Fig. 31.



Numerous axillary buds of *Lonicera*.

Ordinarily, only one bud exists in an axil (fig. 30, *b*); but frequent exceptions to this occur, as in some species of Maple, in Honeysuckles (fig. 31), and in the Walnut. However, one of these is generally much larger than the rest, and is called the *principal* bud, while the others are *accessory*.

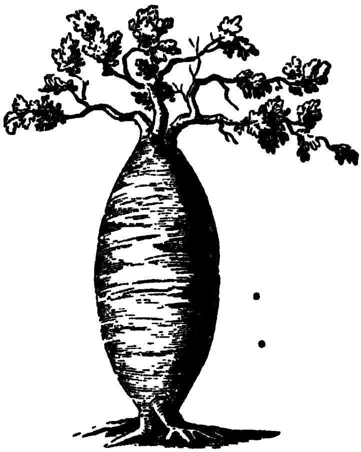
In some plants, as in many Solanaceæ, the buds occur in an irregular position, arising from the stem at a little distance above the leaf-axils. This is supposed to be due to the adhesion of the bud with the stem, and its uplifting with the latter as it lengthens.

The *Trunk* of arborescent plants arises as an herbaceous stem from the seedling, but usually becomes more or less woody before the close of the first season; in the autumn it ceases to develop internodes at its point, and the terminal bud closes up into a resting winter-bud enclosed in leaf-scales; buds of the same sort are produced in the axils of the leaves; and all or part of them open in the following spring, to produce a second generation of axes in the form of *shoots*; the same process being indefinitely repeated, a branched trunk is produced. If the central stem is not much

elongated, and the lateral ramifications are numerous, the result is a shrubby plant; if the growth of the main trunk predominates for a long time, but ultimately slackens, and the side branches grow more, the form seen in ordinary trees appears, where the top of the tree is more or less globose, as in what are called "round-headed" trees, like the elm; while if the growth of the central stem by the terminal bud is predominant throughout life, we have tall straight trunks with comparatively small ascending branches, such as are seen in the Lombardy Poplar, which is an instance of a *fastigiate* tree.

The originally cylindrical form of trunks often undergoes considerable alteration with age, depending upon peculiar modes of development of the woody structure within. Irregular prominences occur commonly on such old timber-trees as have large branches, greater enlargement taking place in the line between the base of the branches and the roots; this is often seen on old Oaks. Some tropical trees produce vast buttress-like projections in the same way. The forms of the trunk of the woody climbing plants of tropical forests present very remarkable irregularities, arising either from a twining habit, or from irregular development caused from lateral pressure or otherwise. In some kinds of *Bombax* (fig. 32), and in *Delabechea* (Bombaceæ), the trunk is swollen out in the shape of a great flask between the root and the main branches.

Fig. 32.



Trunk of a Brazilian *Bombax*.

The *Stock* or *caudex* is an undivided woody trunk, produced by the annual unfolding of a single terminal bud. Its internodes are commonly little developed, so that its sides are marked with the scars of its fallen leaves; sometimes, however, the internodes are developed, and then the stock has a jointed appearance, from scars or actual articulations at the nodes. The stocks of the Cactaceæ are remarkable for their form and consistence (figs. 35–37); their lateral buds are developed into tufts of spines, which are the representatives of the leaves of undeveloped branches.

The stock of the Palms exhibits considerable variety of form. In the Cocoanut- (*Cocos*) and Date-palms the internodes are scarcely developed, and the scars of the leaf-stalks, arranged in spiral order, cover the sides. The same holds good of the stock of *Cycas* and its allies, of *Xanthorrhœa*, and other arborescent Monocotyledons, and also of the stock of the Tree-

ferns (fig. 34). In other cases an internode is more or less developed between each leaf, and the stem is marked by a succession of scars running nearly round the stem (fig. 33), as in *Mauritia* and *Astrocaryum vulgare*; in *Geonoma* and *Chamædorea* the internodes are developed and the nodes thickened, so as to appear externally somewhat like those of the stems of Grasses, but they are not really articulated nor hollow like the latter. The *caudex* of the Palms furnishing the common Cane (*Calamus*) is chiefly distinguished from the last by the slenderness and extreme length

Fig. 33.

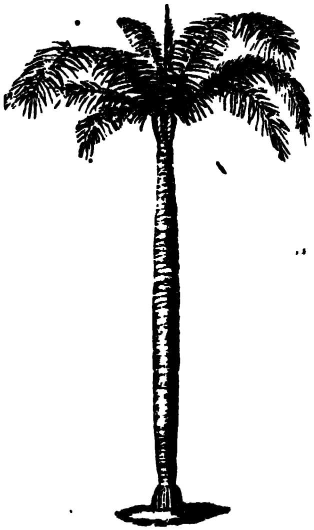


Fig. 34.

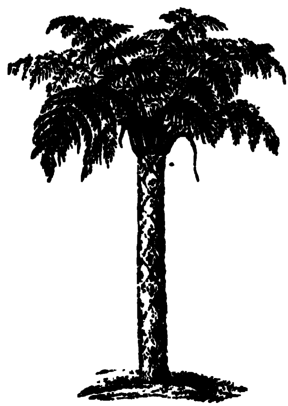


Fig. 33. Palm-tree (*Areca*) with unbranched caudex.
Fig. 34. An arborescent Fern with unbranched caudex.

of the internodes. Many of these Palm-stocks, which are simple in their principal mass, send out axillary buds at or below the ground, which form runners, and ultimately grow up independently of the parent. The aërial stocks of a few branch high above the ground, as in the Doum-palm and in *Pandanus* (fig. 10), where the terminal bud appears to undergo successive bifurcations, but really sends off at intervals single axillary buds, the development of which soon equals that of the parent axis, and causes the deflection of the latter so as to give a forked appearance. A similar mode of growth is observed in certain Hæmodoraceæ (arborescent Monocotyledons, natives of S. America), also in the Liliaceous genus *Yucca.* The stocks of some of the Cactaceæ are undivided, as in *Melocactus* (fig. 36), *Echinocactus*, and *Mamillaria*, &c.; but in others a few branches arise, giving a compound character, as in various species of *Cereus* (fig. 37) and in the leaf-like stalks of *Opuntia* (fig. 35). Analogous structures occur in foreign species of *Euphorbia.*

Fig. 35. Fig. 36. Fig. 37.

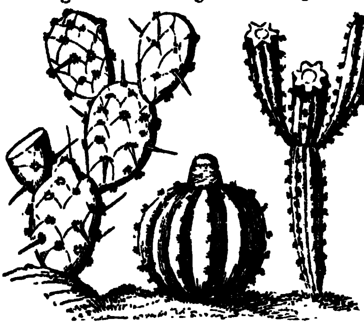


Fig. 38.

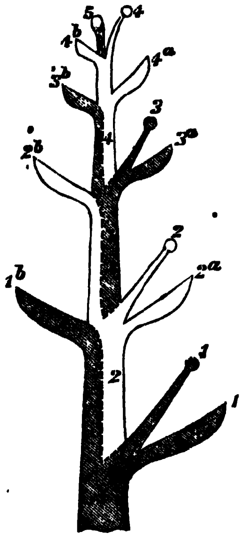


Fig. 35. Stem of *Opuntia*. Fig. 36. Stem of *Melocactus*.
Fig. 37. Cylindrical and ribbed stem of *Cereus*.
Fig. 38. Diagram to illustrate the nature of a sympode, the imperfect separation (so called adhesion) of leaves, and the uplifting of the latter with the growth of the shoot; the primary shoot ending in a terminal bud which is deflected to one side. 1 *a*, one of the leaves of the primary shoot 1, in its ordinary position. 1 *b*, another leaf of the same shoot adherent to or undetached from 2, the shoot produced in the axil of 1 *b*, and carried up with 2 in its upward growth. The shoot 2, 2, with its leaves 2 *a*, 2 *b*, grows in the same manner and others succeed it. The portion of the main axis marked 1, 2, 3, 4, 5 in one vertical line is a sympode, being composed not of one continuous axis of one and the same generation, but of a series of axes of different and successive generations, ranged in vertical order.

Ramification.—The same general methods occur in the branching of roots, of stems, of leaves, and of inflorescences, and indeed are also met with in purely cellular plants, as in Algæ and Fungi. *Caulerpa*, though strictly unicellular, has mimic stem-branches, leaves, and roots. Growth takes place by means of growing points (*puncta vegetationis*), which will be more fully described under the head of Minute Anatomy, and which, in the case of stems, are enclosed within, and form the central terminal mass of the buds. The growing point is terminal or lateral, primary or secondary. If at the end of a shoot or branch it is *terminal* and *primary*, or of the *first degree*; if at the side of a shoot it is *lateral* and *secondary*, or of the *second degree*. In the latter case it is lateral because it is pushed out from the side of the primary shoot beneath its apex, and it is secondary because it is necessarily formed after the primary growing-point, and belongs to a subsequent generation. In like manner we may have in succession tertiary buds, or shoots of the third, fourth, fifth degree, and so on.

Monopodial branching.—By the growth of terminal buds or growing

points the stem is continuously lengthened in one direction; by the development of lateral ones from below upwards (acropetal) it becomes branched. This mode of growth is called *monopodial* (fig. 27).

Dichotomy.—In some instances (*e. g.* the tendrils of some vines, the roots of Lycopods, and frequently in Cryptogams) the terminal growing-point bifurcates. Each pair of new shoots so formed is then of the same degree or order, because each is formed from the same original growing-point and at the same time. The growing-point may, in this manner, divide into several divisions of the same generation or relative order. The shoots formed dichotomously, as above explained, are monopodial or *indefinite* as to their ramification, and may grow equally and regularly, or the growth may be arrested in certain of them, and hence may arise much difference in the appearance of the mode of branching.

Dichasium.—In the foregoing illustrations the terminal growing-point either continues to lengthen as growth goes on, or it divides into divisions of equal degree, though often of unequal vigour. But it very commonly happens that the terminal growing-point or bud ceases to grow after a time (figs. 28, 29). This may happen accidentally or from the effects of frost or other injury, however caused, or it may occur constantly and naturally, as in many trees, *e. g.* the Lilac (fig. 29). When arrest of growth in the terminal bud takes place in the manner just indicated the lateral buds often grow so vigorously, and are so closely placed, that they appear to radiate from the same point as if they were formed by dichotomy of the terminal growing-point. This false or apparent dichotomy is sometimes called a *dichasium* or false cyme (fig. 28).

Sympode.—When in the case of a dichotomous ramification one of the divisions grows more vigorously than the other, or, which amounts to the same thing, when one of them is arrested in its growth or altogether suppressed, then, although the two divisions are of equal degree and age, yet the stronger of the two presents the appearance of and grows in the same direction as the primary shoot, while the smaller one is often pushed on one side, so as to look like a lateral shoot of a subordinate degree (fig. 38). The appearance may thus be that of a continuous shoot formed by the extension of one growing-point and giving off lateral branches; but in reality the shoot is not the result of the extension or bifurcation of one growing-point, but of a number of growing-points of different generations formed in succession one after the other. In this way what is called a *sympode* is produced, and ramification so characterized is sympodial. This arrest of growth may take place regularly or irregularly, producing corresponding variations in the form of the ramifications: thus, supposing a branch to divide into a number of subdivisions by repeated bifurcations to the right hand or to the left respectively, it may happen that all the shoots on the one side are arrested in their growth as compared with those on the other. Or it may happen that the arrest of growth may take place first on one side and then on the other in regular alternate order. All these modifications may be seen in the mode of branching in various cellular Cryptogams as well as in higher plants.

Characters of the Stem and Branches.—In the description of stems and branches generally, certain technical terms are in use, in addition to those above explained. These refer principally to—a. *consistence*; b. *direc-*

tion and habit of growth; c. *form*; d. *condition of surface*; e. *ramification*; and f. *dimensions*.

a. *Consistence.*—The terms *herbaceous* (*herbaceus*) and *woody* (*lignosus*) need no further definition. Some stems are *fleshy* or *succulent* (*carnosus*), as in *Cactus*, &c. Most stems are *solid* (*solidus*); those of the majority of Grasses and the Umbelliferæ (Carrot, Celery, &c.) and the Horsetails (*Equisetum*) are *hollow* or *tubular* (*fistulosus*).

b. *Direction.*—Stems may be truly *erect* (*strictus*), *flexuous* (*flexuosus*) or *nodding* (*nutans, cernuus*). Stems which turn upwards from a horizontal base are called *ascending* (*ascendens*); those lying along the ground without rooting are *procumbent* or *prostrate* (*decumbens, procumbens, humifusus*) (fig. 39); if a prostrate stem roots at its nodes, it becomes *creeping* (*repens*). Slender stems neither lying on the ground nor creeping may be *pendent* (*pendulous*) when growing on rocks &c., and *floating* (*fluitans*) when growing in water. Weak stems also rise from the ground as *climbing* (*scandens*) or *twining* (*volubilis*) stems.

Fig. 39.

Procumbent stem of Thyme.

Climbing stems support themselves in various ways:—the Ivy by tufts of adventitious roots, which attach themselves firmly to foreign bodies; the climbing species of *Clematis* and the Canary-creeper (*Tropæolum peregrinum*) by hooking their leaf-stalks round the support; other plants by *tendrils*, as the Vine, Peas, Cucurbitaceæ, &c.

Twining stems coil themselves spirally round the supporting body, turning sometimes in one direction, sometimes in the other, as in the Hop, Convolvulus, *Cuscuta*, &c. If the direction from below is from the left upwards to the right hand of the observer, supposed to be standing in the position of the body around which the coil winds, the coil is said to be *dextrorse*, if in the opposite direction *sinistrorse*; but by some writers the observer is supposed to stand in front of the coil, and then the application of the terms is reversed. Some of the tropical twiners produce woody trunks resembling large cables.

c. *Form.*—The principal variations in form are designated by terms requiring no explanation, such as *cylindrical* or *terete*, *conical*, *columnar*, &c. If a stem presents thickenings opposite the origin of the leaves (nodes), it is called *knotted* (*nodosus*); the reverse condition, when there are constrictions at intervals, is called *jointed* (*articulatus*). Other terms refer to the shape as displayed in a cross section of the stem. A stem is terete (*teres*) when it presents a circular section; *compressed* (*compressus*) when the section is elliptical; *angular* when the section is polygonal, under which head are distinguished, in a three-angled stem for example, *trique-*

Fig. 40. Fig. 41. Fig. 42.

Fig. 40. A triquetrous stem.
Fig. 41. A quadrilateral or square stem.
Fig. 42. A ribbed stem.

trous if the three angles are sharp (fig. 40), *triangular* if they are about right angles, and *trigonous* when the angles are obtuse or rounded off. When the surface presents a great number of longitudinal ridges, it is called *ribbed* (fig. 42); numerous longitudinal grooves render it *furrowed* (*sulcatus*). In some cases the projecting angles of stems are *winged* (*alatus*), as in many Thistles; in other cases the stem or branch is flattened, so as to resemble a leaf, in which case the term *cladode* is applied, as in *Ruscus* (fig. 43). Such leaf-like branches or *cladodes* are distinguishable from true leaves by their axillary position, mode of origin, internal structure, and by the circumstance that they bear flowers.

Fig. 43.

Foliaceous cladodes of *Ruscus aculeatus.*

The *apex* of a stem or branch is usually pointed or conical, but it may be globose or concave, as in the flower-stalk of a Rose.

d. The *surface* of a stem may be *smooth* (*lævis*) or *striate* (*striatus*), *i. e.* marked with fine grooves and ridges. It may be devoid of epidermal appendages or *glabrous* (*glaber*), or furnished with a more or less dense coat of hairs, bristles (*setosus*), or thorns (*spinosus*). Similar terms are still more commonly applied to the surfaces of *leaves.*

e. *Ramification.*—A stem is either *simple* or *branched*; if the ramification is excessive, it is called *much-branched* (*ramosissimus*). The branches may be *erect, spreading* (*patens*), *outstretched* (*divaricatus*), *deflexed* (*deflexus*), or *pendulous* (*pendulus*). These qualities especially affect the crown or head of trees.

f. *Dimensions.*—Different terms are applied to plants with woody stems, according to their size and mode of branching. A *tree* (*arbor*) is a plant with a woody trunk and branched head. A *shrub* or *bush* (*frutex*) is a kind of dwarf tree, where the main trunk is little developed, but the lateral branches very much so. *Under-shrub* (*fruticulus*) is the diminutive of this.

Sect. 4. The Leaf.

Leaves are the lateral organs issuing from the ascending portion of the stem and its branches *below their growing points*, and in general are flat, expanded plates, produced directly from the superficial part of the stem, and from which, after a certain term of existence, they are removed, either by breaking off at a distinct joint, or by decay.

The simplest leaves occur as flat plates traversed by a nerve, as in Mosses. In many Algæ and cellular Cryptogams processes of the thallus may be seen resembling leaves in form and arrangement, but not in structure. The term *phyllome* is used in a comprehensive sense to signify any leaf, or modification of a leaf, springing from a *caulome* or axis. In some cases, as in Cactus (figs. 35–37), the true leaves are absent, their office being filled by the green stem. Normal leaves, belonging to the vegetative system, are alone taken into account in this chapter; the modified foliar organs composing flowers must be treated separately.

The leaves arise from and mark the *nodes* of the stem; and it has been already stated that it is at the nodes, in the *axils* of leaves, that lateral or axillary buds are as a general rule produced. From this it follows that the *arrangement* of the leaves must be of great importance, not only in reference to their own relative positions, but as determining more or less completely the plans of ramification of stems. It is found that the modes of arrangement of leaves are in accordance with certain general laws; and a particular study of these laws has been pursued, under the name of

Phyllotaxis.—Leaves exhibit two principal types of arrangement: either they are solitary, one only occurring at a node, or two or more spring from the stem at the same level. When the leaves stand alone, they are said to be *alternate* or *scattered* (fig. 44); where two stand at the same level, facing one another, they are called *opposite* (fig. 45); and if more than two originate at one level, forming a circle, the leaves are called *whorled* or *verticillate*. Very rarely two leaves appear to spring from the same node, as in what are called *geminate* leaves (*Solanum*). This condition is supposed to arise from irregular displacement and partial adherence of one of the leaves to the stem, or from division of one leaf into two.

Fig. 44.

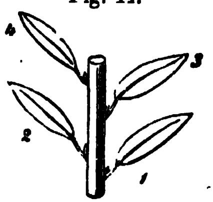


Fig. 45.

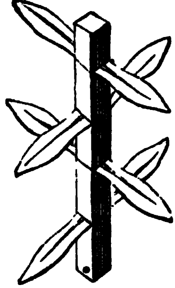


Fig. 44. Diagram of the arrangement of alternate distichous leaves.
Fig. 45. Diagram of the arrangement of decussate opposite and tetrastichous leaves.

Really whorled leaves are not so common as is sometimes imagined, the whorled condition being imitated in some cases, as in many Stellatæ, by an excessive development of interfoliar stipules; truly whorled leaves are seen in *Paris* and *Myriophyllum*. Representatives of the two principal types are found in the embryo of Monocotyledons and Dicotyledons—the former having a solitary *cotyledon*, the latter having two, placed the one opposite to the other (fig. 3); but this opposite arrangement of the cotyledons is not always associated with a like disposition of the true leaves.

Alternate leaves exhibit many modifications of arrangement. Sometimes they are truly alternate; that is, the second leaf is exactly on the opposite side of the stem from the first, and the third exactly over the first: a series of leaves arranged in this way

form two perpendicular rows. Such leaves are termed *distichous* or *two-ranked* (fig. 44); examples of which are found in the Grasses.

If the second leaf is not opposite to the first, but at a point distant from it one third of the circumference of the stem, and the third leaf one third further round, the fourth leaf, likewise distant one third from the preceding, will stand over the first. Leaves so arranged form three perpendicular rows, constituting the *tristichous* or *three-ranked* arrangement, which is common among the Monocotyledons (fig. 46).

Now when a line is drawn round the stem so as to pass regularly from leaf to leaf, we find that its course is *spiral*. In the *distichous* case the spiral line starting from any given leaf completes one circuit and then commences a new one at the third leaf; in the *tristichous* arrangement the spiral completes one circuit and begins a new one with the fourth leaf (fig. 46). The series of leaves included by the spiral line in passing from the first leaf to that which stands directly above it is called a *cycle* (fig. 47); the fraction of the circumference of the stem which measures the angular distance between any two succeeding leaves in a cycle when projected on a plane is termed the *angular divergence*. In

Fig. 46.

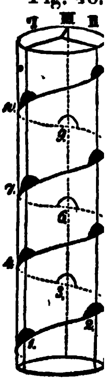


Fig. 47.

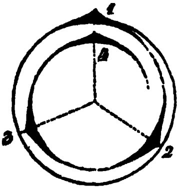


Fig. 49.

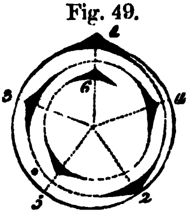


Fig. 48.

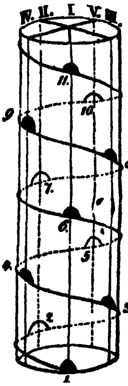


Fig. 46. Projection of the $\frac{1}{3}$ arrangement.
Fig. 47. Horizontal projection of a cycle of the $\frac{1}{3}$ arrangement.
Fig. 48. Projection of the $\frac{2}{5}$ arrangement.
Fig. 49. Horizontal projection of a cycle of the $\frac{2}{5}$ arrangement.

the distichous, represented by the fraction $\frac{1}{2}$, it is one half of 360°, or 180°; in the tristichous, or $\frac{1}{3}$, it is 120°.

These fractions not only represent the angular divergence, but

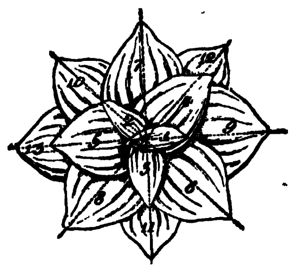
also the entire character of the arrangement; for the numerator, as is seen, indicates the number of turns of the spiral forming a cycle, while the denominator expresses the number of leaves in that cycle.

In the *pentastichous*, *quincuncial*, or *five-ranked* arrangement the sixth leaf stands over the first (figs. 48 & 49), commencing a second cycle; but the spiral line passing through the first five leaves makes *two* circuits round the stem; moreover the successive leaves stand at a distance from each other of two fifths of the circumference of the stem, or 144°; while the expression of the angular divergence, $\frac{2}{5}$, indicates also the number of turns round the stem in the cycle, and the number of leaves in the cycle, as before.

The next degree of complexity of the arrangement is where eight perpendicular rows of leaves exist, and the ninth leaf is over the first. In this case the spiral takes *three* turns in completing the cycle; and the expression $\frac{3}{8}$ indicates three eighths of the circumference, or 135°, the angular divergence of the successive leaves.

When we place the foregoing figures together, thus: $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, it will be observed that each fraction has its numerator composed of the sum of the numerators of the two preceding fractions, and its denominator of the sum of the two preceding denominators; and it is really found that all higher complications, in normal conditions of stems, exhibit some further indication of the same ratio, and are marked successively by $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{34}$, $\frac{21}{55}$, &c.*

Fig. 50.



Rosette of leaves of *Plantago media*, seen from above; the leaves on the $\frac{3}{8}$ type.

The simpler forms of arrangement are the most common; those marked by higher fractions are chiefly found in plants with the leaves much crowded, as in the House-leek. The scales of the cones of Pines and Firs offer good examples of these spiral arrangements. The following examples may be mentioned for observation:—

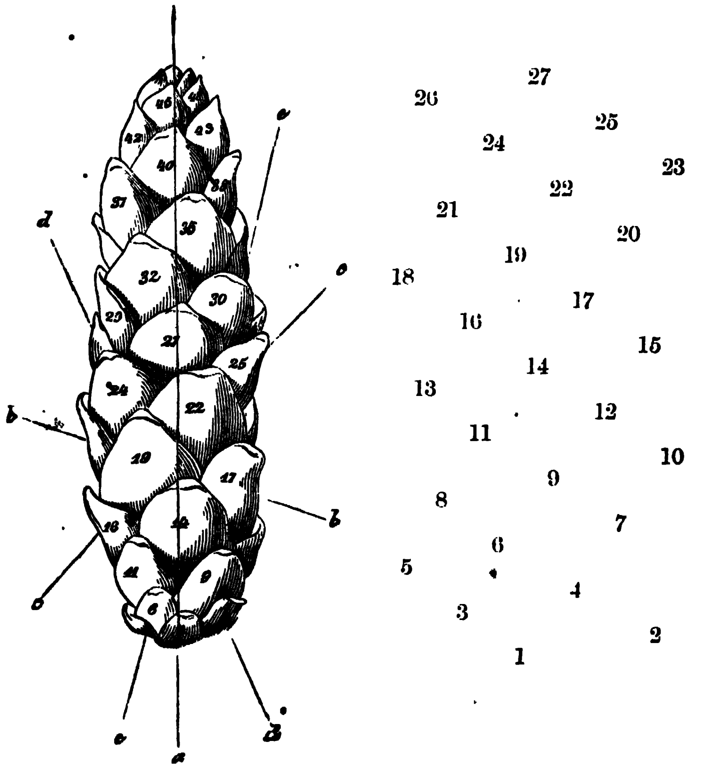
Plan $\frac{1}{2}$. Leaves of Grasses, *Vanda*, *Iris*, *Gladiolus*, Elm, Lime, &c.

* [The mathematician will observe that these fractions are the ***successive convergents of the continued fraction*** $\frac{1}{2+}\frac{1}{1+}\frac{1}{1}$ &c., and that any leaf being taken as No. 1, the second must lie between 120° and 180° from it. Its position, corresponding successively to each of the above series of fractions, oscillates alternately on either side of a point indicated by the limiting value of the continued fraction, viz. 137° 30′ 28″+.—G. H.]

Plan $\frac{1}{3}$. Leaves of Sedges (*Carex, Scirpus*), Tulip, Alder, Birch, &c.
Plan $\frac{2}{5}$. Leaves of Apple, Cherry, Poplar, Oak, Walnut, &c.
Plan $\frac{3}{8}$. Leaves of Flax, Plantain (*Plantago*) (fig. 50), Holly, Aconite, &c.
Plan $\frac{5}{13}$. Eyes (buds) of Potato-tubers, cones of *Pinus Strobus* (fig. 51).
Plan $\frac{8}{21}$. Cones of Spruce-fir (*Abies excelsa*).

When the leaves are very numerous and much crowded, it is often difficult to trace the *fundamental spiral*, as the vertical ranks are not

Fig. 51.



Cones of *Pinus Strobus*, with the scales in the $\frac{5}{13}$ arrangement.

evident. In these cases the arrangement is ascertained by studying the *secondary* spirals which appear. These are more or less numerous, according as the fractional expression of the fundamental spiral is higher.

For example, in examining the cone of the White Pine, a complex spira arrangement is at once recognized, which will be understood by

reference to the adjoining diagram (fig. 51). Assume any scale as No. 1. Select the scale over it, in as nearly a vertical line as possible, such as that numbered 14 in fig. 51. Secondary spirals parallel to each other will be seen running to the right and to the left hand. Such are indicated by the numbers 1, 6, 11, 16, &c. to the left, and by 1, 9, 17, &c. to the right of the reader. Or, again, very *depressed* spirals are formed by the scales marked 9, 11, 13 (not seen) to the left, and by 6, 9, 12 (not seen) to the right. Of all such spirals, select *the two most elevated*, which pass by and overlap the scale immediately over that chosen as No. 1. These will be the spirals indicated by the numbers 1, 6, 11, 16, &c. to the left of No. 14, and by 1, 9, 17, 25, &c. passing to the right hand of that scale. Count the number of secondary spirals parallel to these two respectively. There will be found to be *eight* such parallel spirals in all sweeping round to the right; and *five*, such as 1, 6, 11, 16, &c., to the left. Take the lowest of these two numbers, or 5, as the numerator, their sum, 5+8, or 13, as the denominator, and $\frac{5}{13}$ will be the fraction required.

To *prove* this, numbers must be assigned to every scale of at least the first cycle, *i. e.* those included between No. 1 and that numbered 14 in the figure.

Starting with the scale assumed as No. 1, add 8 (that is, the number of parallel spirals to the right) to 1, and write 9 on the next scale, as in fig. 51. Add 8 again, and write 17 on the next, and so on.

Again, add 5 to 1, and write 6 on the adjacent scale on the left-hand spiral; add 5 to 6, and write 11 on the next, and so on.

Two entire secondary spirals intersecting at No. 1 will thus be numbered.

To number any other scales, we may start from either of these spirals, always adding 5 to the number of any scale on going from right to left, and 8 on going from left to right: thus,

$$6+8=14. \quad 14+8=22,$$
$$\text{or, } 9+5=14. \quad 17+5=22.$$

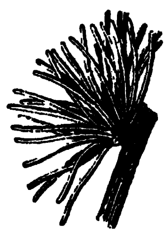
So that we can assign by either method the numbers 14 and 22 to the proper scales. Similarly all the scales of the cone can be numbered. Only those of a lower number than 6 and 9 are obtained by *subtraction* of 8 and 5. Now, it will be seen that 14 will be the number of the scale directly over No. 1. This *proves* that the denominator is correct, for there will be 13 scales in the cycle.

Secondly, having, we will assume, numbered all the scales of the cycle between Nos. 1 and 14, if the cone be held erect, and is made to revolve while the eye passes from No. 1 to No. 2, then on to No. 3, &c., up to No. 14, the observer will find that he revolves the cone *exactly five times.* In other words, a spiral line passing through the scales 1, 2, 3, 4 . . . up to 14, which constitutes one cycle, will coil five times round the axis.

The perpendicular distance between the points of origin of successive leaves is dependent simply on the degree of development of the internodes of the stem. These may be so short that, as in the common Stone-crop (*Sedum acre*), *Araucaria imbricata*, &c.,

the leaves overlap more or less along the developed axis; such leaves are termed *imbricate*; and this condition is very common in the leaf-scale forms of the leaf. A great number of well-developed leaves are often crowded together by the non-development of internodes at the base of the flowering stems of perennial herbs, such as the various Saxifrages, the Turnip, Dandelion, &c.; and where these so-called "radical" leaves are arranged with some regularity, and spread out horizontally as in the House-leeks, they are said to be tufted, *cæspitose* or *rosulate* (fig. 50).

Fig. 52.



Fasciculate leaves of the Larch.

A somewhat similar condition occurs upon branches of some trees, on which a number of leaves appear to spring from one point, as in the Larch (fig. 52) and the Berberry; the collections of *fasciculate* leaves really belong to a branch the internodes of which are not developed, so that they all spring at once from the leaf-axil in which the branch-bud was formed.

In other Conifers the number of leaves in these bundles is smaller and very regular and characteristic; *e. g.*, in *Pinus sylvestris* two leaves are thus associated, in *P. Cembra* three, in *P. Strobus* five, &c. In those buds of the Larch which afterwards unfold into shoots, the transition from a *fasciculate* into a regular spiral arrangement becomes evident.

Opposite and whorled leaves likewise exhibit great regularity. The number of leaves in a whorl is here also sometimes expressed by a fraction, which is enclosed in a parenthesis; the denominator in this case indicates the number of leaves in one circle.

Fig. 53.

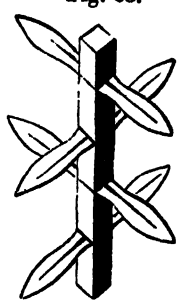


Diagram of decussating pairs of leaves.

Examples of those in true leaves are furnished by the following plants:—

($\frac{1}{2}$) plan (opposite leaves). Pinks, Labiatæ.
($\frac{1}{3}$) " *Lysimachia vulgaris*, *Trillium*.
($\frac{1}{4}$) " *Paris quadrifolia*.
($\frac{1}{5}$) " *Myriophyllum pectinatum*.

Sometimes the numbers vary on different parts of the same stem, as in *Hippuris*.

When leaves are opposite, the pairs are almost invariably alternate *; that is, they cross at right angles, the third pair standing over the first. Such leaves are called *decussate* (fig. 53). With whorls of three leaves,

* An exception is seen in *Potamogeton*.

again, we usually find a similar alternation; the leaves of the second whorl stand over the intervals between those of the first, the leaves of the third whorl standing over the leaves of the first.

[There is reason to believe that the arrangement of alternate leaves has resulted from the development of the internodes between opposite leaves; for when the latter occur at the base of a stem and alternate leaves above, it will be found that, as the internodes are gradually developed, the leaves always appear in succession in a spiral order; and most frequently the sixth falls over the first, that being the *last* out of three pairs of decussating leaves; or else the ninth falls over the first, that being the *first* leaf of the fifth pair. The leaves on becoming alternate soon cease to be decussating, and gradually acquire their proper angular divergence. Moreover, as decussating pairs of leaves can give rise to the ordinary series of fractions, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, so alternating whorls of "threes" give rise to the series $\frac{2}{7}$, $\frac{3}{11}$, $\frac{5}{18}$. Both kinds can be well studied in the Jerusalem Artichoke.—G. H.]

2
.
5
3 . 8   7 . 4
9
. .
6
.
1

Diagram illustrating the order of development of leaves when the internodes are beginning to be formed, and before the proper angular divergences exist.

Conversely, if the internodes between the component leaves of any individual spiral cycle were undeveloped, while those between *successive* cycles were lengthened, a verticillate arrangement would result. In certain plants (for example, the Myrtle, the Antirrhinum) alternate and opposite leaves occur on the same stem. This is the case also in those Dicotyledons where the true leaves succeeding the opposite cotyledons are alternate, as in the Scarlet Bean, Mustard, &c.

It is requisite to distinguish between *simultaneous whorls*, where the parts composing it are developed simultaneously, and *successive* whorls, where the parts are developed successively, but are brought together by the non-development of the internodes. The arrangement of the leaves in the manner above indicated is to a great extent connected with the deposition of the fibro-vascular bundles of the stem. It should, however, be stated that the arrangement of the leaves on the stem is not always the same as that on the branches.

Certain terms are in common use in descriptive works to indicate the absolute position of the leaves upon the stem. The name *radical* leaves is applied to those, usually of larger size than the

rest, which are often found collected at the base of flowering stems of herbaceous plants, such as the Dandelion, Lettuce, Turnip, *Plantago* (fig. 11, p. 21), &c. The ordinary leaves of the stem are sometimes distinguished as *cauline* or *stem-leaves*, while the term *ramal* is occasionally used for those on the shoots of trees and shrubs when these present special characters.

The leaves belonging to the inflorescence are called **bracts.** Their phyllotaxis generally agrees with that of the stem-leaves.

The point whence a leaf springs from the stem is commonly called the *insertion*. Leaves are either *articulated* there, separating when dead by a distinctly characterized line of fracture, or they merely wither down, and leave their bases as a ragged covering to the stem; the latter condition occurs mostly in leaves with sheathing bases.

A perfect leaf is divisible into two regions (fig. 54)—the *blade* or *lamina* (*b*), and the *leaf-stalk* or *petiole* (*c*); the latter, when present, may be more or less completely represented by a *sheath* or *vagina* (*a*), partly or wholly embracing the stem from which it arises. At the base of the petiole often occur distinct leaf-like appendages, called *stipules*. All parts of the leaf—blade, stalk, and stipules—are much subject to modification, and may even exist in the forms of *tendrils*, *spines*, *pitcher-like* organs, &c., very unlike

Fig. 54.

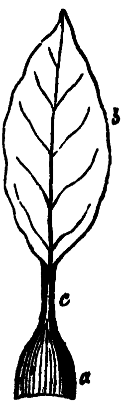
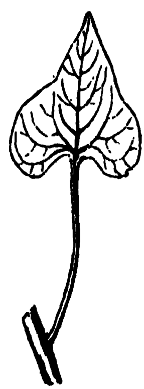


Diagram of the regions of a leaf: *a*, sheath; *b*, blade; *c*, stalk.

Fig. 55.



A stalked simple leaf equally cordate at the base.

regular leaves. These metamorphosed leaves, or parts of leaves, are best treated of separately.

The stalk-like petiole (fig. 55), most common in Dicotyledons, always has the base slightly widened out at its point of emergence from the stem; in the leaves of Palms, the Banana, Scitamineæ, &c. the base is expanded so as to embrace the stem, while in the Grasses the petiole is entirely represented by a sheath (fig. 59). The green part of the leaves of the Hyacinth and other bulbous plants is the blade, and will be found continuous below with a colourless, fleshy, petiolar portion, forming one of the "coats" or sheaths of the bulb (fig. 17, p. 25).

The leaf may, however, be represented by one only of the regions. It is very common to find leaves without distinct petioles, the blade springing directly from the stem: such leaves are called *sessile* (fig. 56). On the other hand, the petiolar region may exist without the blade; and among the cases of this sort a considerable variety of conditions is met with. Petiolar structures, devoid of laminæ, and more or less reduced to scales or membranous sheaths, are commonly found on subteranneous stem-structures, such as bulbs, rhizomes, &c., whence we have denominated this part of the stem the "leaf-scale region." Similar scales appear in place of green leaves in the "true-leaf" region of various parasitic plants, such as *Orobanche*, in which the leaves have no physiological function to perform; and they recur periodically on the stems of arborescent plants which form winter buds, in the shape of bud-scales. In the true-leaf region the blade is either supported on a stalk-like or sheathing petiole, or is sessile. The sessile con-

Fig. 57.

Fig. 56.

Fig. 58.

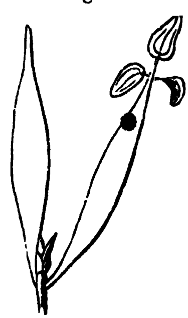


Fig. 56. A sessile leaf. Fig. 57. Phyllodium of an Acacia.
Fig. 58. Two phyllodia of *Oxalis latipes*, one with a ternate blade.

dition is generally more common toward the upper part of stems and shoots; and in the *bracts* or leaves belonging to the inflorescence the petiolar region is comparatively seldom developed. The

first leaf (*Vorblatt* of the Germans) on a branch in many Monocotyledons is of a different form from the rest, and is found in the angle between the branch and the stem from which it springs. In Dicotyledons there are often two such leaves at the base of a branch, right and left, and occasionally they are united into a tube. They are sometimes formed after the other leaves according to Hofmeister.

In some families the true-leaf region is clothed with petioles expanded into the form of laminæ; these are called *phyllodes* (figs. 57 and 58), and in such cases the true laminar region is often partially or entirely suppressed.

The transition from the petiolar leaf-scale organs into perfect leaves with sheathing petioles may be observed not only in bulbs, but in many Grasses with creeping stems, which exhibit, at the junction of the leaf-scale and true-leaf regions, sheaths surmounted by short green lancet-shaped laminæ, increasing in length in successive leaves.

Stipules.—When the petiole appears as a distinct leaf-stalk, it is often accompanied by a pair of more or less distinct foliaceous appendages at its base, called *stipules*. When these exist, the leaf is called *stipulate* (fig. 63); when they are absent, *exstipulate*.

The presence or absence of stipules is often a very constant character of Natural Orders. The various forms of stipulate petioles form a kind of transition to the petioles with sheathing bases.

Petiole.—The *pĕtiole* is usually of semicylindrical form, with the flat surface above; not unfrequently this upper surface is channelled (*canaliculate*), giving a more or less crescentic section; in a few instances, especially in the Aspen, it is laterally compressed. Where it is cylindrical its structure is like that of a branch.

The stalk-like petiole is either *simple*, when it supports a single blade, or it is branched or *compound*, when the blade is composed of a number of distinct leaflets; the branches are sometimes called *partial petioles*, and may even be articulated at their points of origin from the primary petiole.

Compound petioles supporting the leaflets of compound leaves are known from branches, which at first sight they resemble, by arising independently from the stem, by having buds in their axils, and by the absence of any indication of a leaf immediately beneath them.

Phyllodes.—The flattened or leaf-like petiole, called a *phyllode*, resembles a lamina, but is known by standing edgewise on the stem—that is, with its flat faces parallel with the direction of the

stem; in some cases *phyllodes* exist without true laminæ (fig. 57), in others the laminæ are more or less developed at the summit (fig. 58).

Striking examples of *phyllodia* with or without laminæ are furnished by various species of *Acacia* (figs. 57 & 101), in many of which the blade is present, compound and bipinnate.

Vagina.—The sheathing portion or *vagina* is the only portion of the petiole which is developed in certain plants, as in the Grasses and Sedges (figs. 59–61), in which it forms a complete sheath to the stem, and passes at once into the blade at the top: this sheath is merely rolled round the stem in the Grasses; but its margins are not disunited, but form a tube, in the Sedges. The vaginal petiolar region is more or less distinctly evident in many Monocotyledonous leaves which at first sight appear to be sessile, as in the Tulip, Hyacinth, &c.; and it is generally more or less developed at the base where a distinct leaf-stalk exists in this class, as in the Palms and, above all, in the Musaceæ. In many Dicotyledons also the base of the petiole is enlarged into a sheath, as in Umbellifers (fig. 62).

Fig. 59. Fig. 60. Fig. 61. Fig. 62.

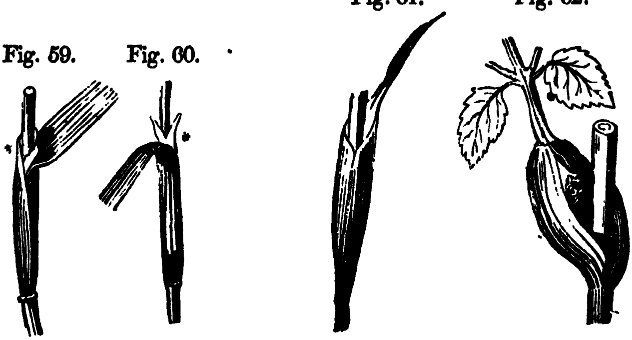


Fig. 59. Leaf-sheath of a Grass, with an entire *ligula*, *.
Fig. 60. Leaf-sheath of a Grass, with a bifid *ligula*, *.
Fig. 61. Leaf-sheath of *Eriophorum*.
Fig. 62. Sheathing base of the petiole of *Angelica*.

Sometimes the petiole is *winged* (*alate*), as when a narrow plate of the blade structure springs from its margins; in certain cases these wings are *decurrent* down (or, rather, are continuous with the sides of) the stem from which the leaf arises, as in many Thistles, *Verbascum*, &c., producing a *winged* or *alate* stem.

Cicatrix.—The petiole is ordinarily more or less distinctly jointed to the stem; and when the leaf falls, it leaves a more or less extensive well-defined scar upon the stem, called the *cicātrix*; in

woody Dicotyledons there is generally a little protuberance under the cicatrix, which is termed the *pulvinus*. In Monocotyledons the cicatrix is usually very broad, from the base of the petiole embracing the stem widely. In some cases the petiole is not regularly disarticulated, but withers down; but then the decay generally terminates at a definite point a little above the base, leaving a portion of the latter in the form of a scale-like or tooth-like process projecting from the stem.

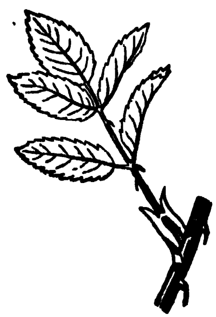
Tooth-like processes left by the decay of the petioles may be seen on the underground stem of the common Primrose &c., and on the trunks of certain Palms.

Fig. 63.

Leaf of *Lotus* with free stipules.

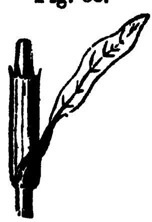
Stipules.—The *stipules* or leaf-like appendages of the petiole usually stand at the base of the petiole, one on each side, free or adherent to it (fig. 63). The *free* leafy stipules are sometimes highly developed, and in *Lathyrus Aphaca* they exercise the functions of the blade, the leaves of this plant consisting merely of a petiole destitute of a lamina. When the margins of the stipules next the petiole are continuous with that organ, forming as it were wings to it (*Rosa*), they are called *adnate* (fig. 64). They are also often united by their margins independently of the petiole, or, in other words, are not separated from each other (*connate*): thus in the Plane-tree and in *Astragalus* they are united by the outer mar-

Fig. 64.



Compound (pinnate) leaf of the Rose, with adnate stipules.

Fig. 65.



Ocrea of *Polygonum*.

gins (turned away from the petiole) so as to form a kind of leaflet on the opposite side of the stem (*intrapetiolar*); in *Potamogeton*

they are united by their inner margins *above* the petiole, so as to form a compound *axillary* stipule; in the Polygonaceæ they are not only united on this side, but also by their outer margins on the other side of the stem, thus forming a short tubular sheath round the latter, called an *ocrea* (fig. 65). All the above cases relate to stipules of single leaves; but similar coherence or lack of disunion occurs in the stipules of opposite leaves, where it is not uncommon to find the two stipules which stand between the leaves, at back and front, more or less confluent into a single leaf-like or scale-like body (*interpetiolar stipule*), so as to form a kind of whorl with the true leaves.

This interpetiolar confluence of the stipules is very characteristic of the Order Rubiaceæ; and the apparent whorls of the *Stellatæ* (*Galium*, &c.) often exhibit a confluence of the highly developed leaf-like stipules.

At the summit of the sheath of the leaf of Grasses exists a little membranous scale, connecting the blade with the epidermis of the stem; it is either entire or forked at the top (figs. 59 * & 60 *); this structure, called the *ligule*, is a mere excrescence from the stalk.

The stipules of some plants fall off at an early period. This is the case with the interpetiolar stipules of various Rubiaceous plants. It also occurs commonly when the stipules form the outermost envelopes of the leaf-buds, as in Magnoliaceæ, *Ficus elastica*, the Beech tree, &c.

Small secondary stipules exist at the base of the partial petioles of some compound leaves, especially of Leguminosæ (*Desmodium*); they are called stipels (*stipellæ*).

For convenience of description the stipule has been here treated as if it were uniformly of the same nature, varying only in form, position, &c. In point of fact, however, the morphological nature of the stipules varies in different plants: sometimes they represent mere excrescences from the petiole; at other times they consist of the lower leaflets of a compound leaf (*Lathyrus*), or they may be leaves formed on a contracted and rudimentary axillary branch.

Lamina.—The lāmina or blade (*b*, fig. 54) of the leaf constitutes the most important part of the structure, and exhibits the greatest variety in its forms, which latter require to be studied in detail, as they often furnish the principal characters for the discrimination of species of Flowering Plants and Ferns. It is ordinarily a flat plate, possessing an *upper* and *lower surface*, turned respectively towards the sky and the earth, two *margins*, a *base*, and an *apex*.

In plants of succulent habit the thickness of the leaves is often so great that the sides are as broad as the surfaces, or they are more or less confounded in a *cylindrical*, *prismatic*, or some similar form (*Mesembryan-*

themum); and similar external forms are presented by the cylindrical or flattened fistular leaves of the Onion, &c.

If the blade stands alone upon an undivided petiole, or is sessile on the stem, it is called *simple* (figs. 54, 55). Where the petiole is branched, and bears more than one distinct blade, the leaf is *compound* (fig. 64), and its separate blades are called *leaflets*. Both simple leaves and leaflets may be *entire*—that is, the blade may be undivided at its margins; or it may be more or less deeply incised or lobed. The divisions or branchings of such leaves are analogous to the monopodial branching of the stem (p. 38).

Form.—The general form of simple and compound leaves, and the character of the subdivisions of the blade of simple leaves and of leaflets, are associated with the plan of arrangement of the skeleton of the leaf. The solid framework of leaves is composed of woody structures which when large are usually termed *ribs* (*costæ*), the small divisions being called indifferently *nerves* or *veins*. The plan of arrangement of the framework is called the *nervation* or *venation*; the ordinary custom is to call the principal ribs *nerves*, and the smaller branches *veins*. When a distinct principal rib, continuous with the petiole, exists, it is called the *midrib*.

The superabundance of terms is an inconvenience here as in many other departments of Botany. Where it is necessary to select, it is advisable to choose those terms which are least objectionable as not involving hypothetical notions of function.

Nervation or Venation.—The modes of nervation of leaves may be classed under four principal heads:—

1. *Straight-* or *parallel-nerved* (*folia parallelinervia*), when (with or without a midrib) the principal ribs run in more or less parallel lines from the base to the summit (fig. 66).
2. *Curvinerved* (*f. curvinervia*), when the principal ribs run in curves from the base to the summit (fig. 67), or from the midrib to the margin (fig. 68)—differing little from the foregoing, but occurring in broader leaves.
3. *Palminerved* (*f. palminervia*), when the principal ribs radiate from a point at the base of the leaf (fig. 69).
4. *Penninerved* (*f. penninervia*), when the strong midrib gives off the side-ribs at a more or less acute angle, like the blades on the shaft of a feather (figs. 68 & 70).

The term *triple-nerved* (*triplinervia*) is sometimes used for a modification of No. 4, approaching to No. 3, when the midrib gives off on each side near the base a strong side-rib, which runs up within the margin towards the summit. *Feather-ribbed* (*penninerved*) and *hand-ribbed* (*palminerved*) leaves are most common among the Dicotyledons, but they

occur also in many Monocotyledons,—the former, for example, in many Palms, Musaceæ, Zingiberaceæ (fig. 68), &c.; the latter in the Fan-palms,

Fig. 66.

Fig. 67.

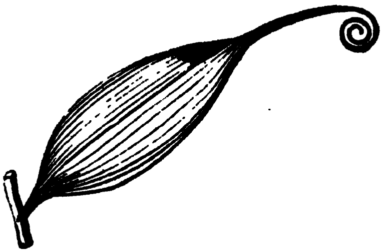


Fig. 68.

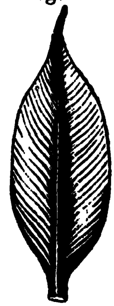


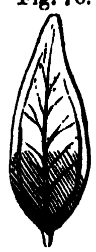
Fig. 66. A parallel-nerved leaf.
Fig. 67. A curvinerved leaf of *Gloriosa superba*, terminating in a tendril.
Fig. 68. A penninerved leaf of *Canna*, with curved secondary nerves.

Smilaceæ and Dioscoreaceæ, &c., where there is a transition to a *curved-ribbed* condition (fig. 67), which, with the *straight-ribbed* (fig. 66), is most common in the Monocotyledons. *Straight-ribbed* leaves occur not

Fig. 69.

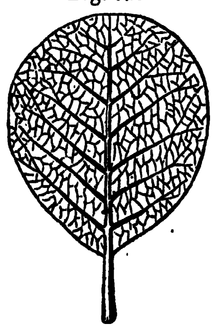
A palminerved serrate leaf.

Fig. 70.



A penninerved entire leaf with a marginal vein.

Fig. 71.



A subrotund, entire, penninerved leaf.

unfrequently in Dicotyledons, as in *Lathyrus*, &c. The most important distinction in the ribbing of the two groups is, that in Dicotyledons the

main rib or ribs branch repeatedly at more or less acute angles, and anastomose by their slender twigs, so as to form a netted or reticular framework; while in most Monocotyledons the branches passing from the main ribs go off nearly at right angles, become suddenly much more slender, and form a kind of square *latticed* or *cancellate* framework when they are strongly developed (fig. 76).

Forms of Leaves.—The general outline of leaves or leaflets is indicated by certain technical terms, such as:—*circular* or *orbicular* (*Hydrocotyle, Tropæolum majus*) (fig. 87); *roundish* or *subrotund*, approaching the fore-

Fig. 72.

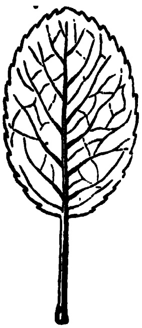


Fig. 73.

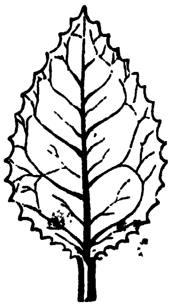


Fig. 74.

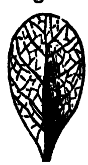


Fig. 75.

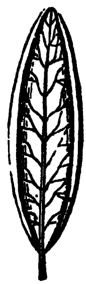
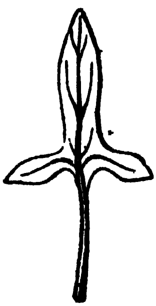


Fig. 72. An elliptical serrate leaf.
Fig. 73. An ovate, acute, and dentate leaf; venation arched.

Fig. 74. An obovate entire leaf.
Fig. 75. An entire lanceolate leaf, edges revolute.

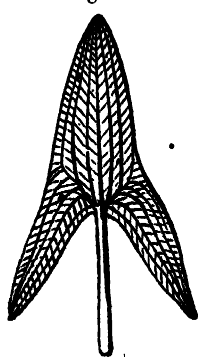
going (fig. 71); *elliptical* (fig. 72); *ovate*, egg-shaped with the broad end nearest to the stalk (fig. 73); *obovate*, the same shape, with the narrow

Fig. 77.



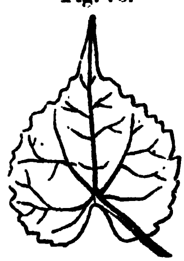
A hastate leaf.

Fig. 76.



A sagittate leaf.

Fig. 78.



A cordate and abruptly acuminate leaf.

end nearest to the stalk (fig. 74); *lanceolate* or lance-shaped (fig. 75); *reniform* or kidney-shaped (fig. 79); *rhomboidal*; *triangular*; or the reverse of this, *cuneate* or wedge-shaped (fig. 88); *deltoid*; *spatulate* or spatula-shaped (fig. 80); *ensiform* or sword-shaped (as in the Garden-flag); *linear*, a long narrow form with parallel margins (fig. 81); *subulate* or awl-shaped, a slender, short linear form soon ending in a point (fig. 82); *acerose*, needle-shaped and rigid (Pines, Juniper, &c.).

Fig. 79.

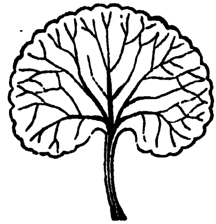
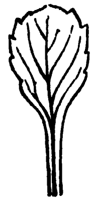


Fig. 80.



Figs. 81, 82.

Fig. 83.

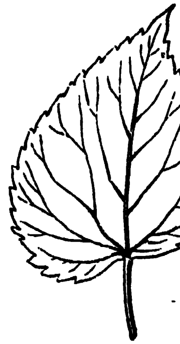
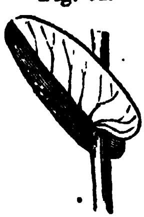


Fig. 79. A reniform crenate leaf. **Fig. 80.** A spathulate leaf. **Fig. 81.** A linear leaf. **Fig. 82.** A subulate leaf. **Fig. 83.** An obliquely cordate, serrate, and acuminate leaf.

Sometimes the forms are intermediate between some of the foregoing, in which case two of the terms are combined, such as *ovate-lanceolate*, signifying a leaf broader than *lanceolate*, and with the lower half wider, as in ovate; *linear-lanceolate*, a long and narrow lance-shaped blade, and so on. The term *oblique* is applied to leaves where the portions on either side of the midrib are unequal, as in the Begonias, Lime, Elm, &c. (fig. 83).

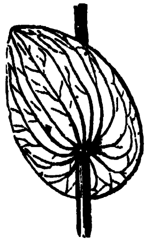
Base of the Leaf.—Special terms are also required to describe the character of the base of the leaf. Thus, *sagittate* or arrow-shaped (fig. 76); *hastate* or dart-shaped (fig. 77); *cordate*, the shape of a heart on playing-cards, with the broad end nearest to the stalk (fig. 78); *obcordate*, the same shape, with the point attached to the stalk (fig. 108); *cordate at the base* may be added to *ovate*, *elliptical*, or other form, where this condition exists; if a *sessile* leaf has a cordate base, it becomes *auriculate* or *eared* (fig. 84) when the borders are free, *amplexicaul* or *clasping* if they adhere to the stem. The last form is a transition to the *decurrent* state. When the posterior lobes of a sessile leaf extend round the stem completely and become confluent on the other side, the stem appears to *run through* the leaf, and the leaves are called *perfoliate* (fig. 85); when the basilar lobes of a pair of opposite leaves cohere on each side, so as to produce a similar condition, the leaves are termed *connate* (fig. 86). Sometimes the blade is gradually narrowed towards the petiole, and becomes *attenuated* at the base; when the blade passes still more gradually into a broad-winged stalk, a *spatulate* form results.

Fig. 84.



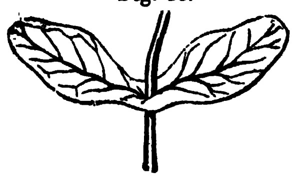
An auriculate leaf.

Fig. 85.



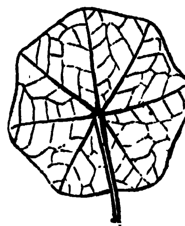
A perfoliate leaf.

Fig. 86.



Connate leaves.

Fig. 87.



A peltate orbicular leaf.

Another character relating to the base is the mode of attachment of the blade to the petiole. Usually the midrib, or set of primary ribs of the blade, is in a direct line with the petiole; but sometimes the ribs, as they pass from the petiole into the blade, separate and radiate horizontally from the top of the stalk, so that the latter appears to be inserted into the *back* of the leaf; such a condition is called *peltate*, and occurs in *Tropæolum majus* and other plants with *orbicular* leaves (fig. 87).

Fig. 88.

A cuneate and mucronate leaf.

Apex of the Leaf.—The apex or point of the leaf has certain characters: it may be *acute*, or sharp (fig. 66); *acuminate*, or with the point drawn out gradually (fig. 68), or abruptly (fig. 78); or *mucronate*, when it is tipped with a *spine* (fig. 88). It may also be *obtuse*, when an ordinarily pointed form is suddenly rounded off at the tip; *emarginate*, when there is a shallow notch where the point should be; *retuse*, when a notch of this kind is deep: this last form approaches to the *obcordate* (fig. 108).

Margin of the Leaf.—The margins of the leaf are either *entire*, that is, with an unbroken edge (fig. 71); *crenate*, when they exhibit a series of small rounded teeth or scallops (fig. 79); *dentate* when the teeth are acute and pointed radially (fig. 73); *serrate*, when sharp teeth point towards the apex (fig. 83); *retroserrate*, when sharp teeth point towards the base. If there are coarse teeth, the margins of which are again more finely toothed, as in the Elm, the leaves are *doubly serrate* (or *doubly dentate*). Sometimes it is requisite to say, *irregularly toothed*, or *incised*, as in many Thistles; and these teeth, as well as those of regularly dentate or serrate leaves, may be tipped with spines, when they are termed *spinose-serrate*, &c. When the outline exhibits shallow wavy curves, it is sometimes called *repand* (figs. 86 & 87). The margin may also be *revolute*, or rolled back toward the lower face (fig. 75), or *involute* when rolled round on to the upper surface. Sometimes, through excessive growth of the marginal parenchyma, the edges of the leaf are *undulated* (as when the edge of a strip of paper swells from being wetted (fig. 95)).

Lobed Leaves.—A very large number of simple leaves, and of leaflets of compound leaves, are divided more deeply between the principal ribs; to such the general name of *lobed* leaves is often applied, and the more or less distinct parts are called lobes; thus we may have *bilobed* (fig. 89), *trilobed* (fig. 90), and so on, according to the number of the divisions.

Fig. 89.

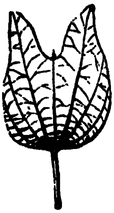


Fig. 90.

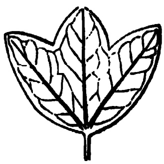


Fig. 91.

Fig. 92.

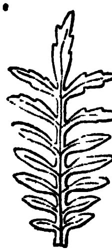


Fig. 93.

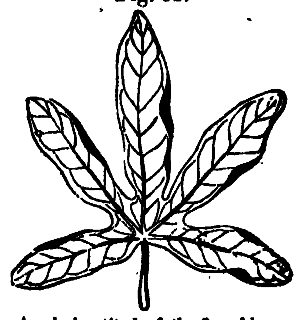
Fig. 89. A bilobed leaf.
Fig. 90. A trilobed leaf.
Fig. 91. A pinnatifid leaf.
Fig. 92. A pinnatipartite leaf.
Fig. 93. A pinnatipartite lyrate leaf.

But it is found requisite in Descriptive Botany to subdivide lobed leaves into more definite classes; of these there are two principal types, defined by the character of the *ribbing*. When the ribs are arranged on the feathered plan, we first take the prefix *pinnati-* (*feathered*), and subjoin to this a word indicating the degree or kind of division, thus: *pinnatifid* (*feather-cleft*), if the broad notches between the lobes extend from the margin to about halfway between this and the midrib (fig. 91); *pinnatipartite*, if the notches extend nearly to the midrib (fig. 92); *pinnatisect*, if the separate lobes are almost free, and merely connected by a narrow strip of parenchyma. Certain less frequent modifications of these forms of the feathered type are conveniently distinguished by technical terms, such as:—*sinuate*, a form either of the *pinnatifid* or *pinnatisect* leaf, when the excavations and the apices of the lobes are rounded, as in the

Fig. 94.

A palmifid leaf, the nine acute lobes serrated.

Fig. 95.



A palmipartite leaf, the five oblong lobes undulated.

common Oak-leaf; *lyrate*, a pinnatifid or pinnatipartite leaf, with the end lobe much larger than the rest (fig. 93); *runcinate*, a *lyrate* or simply *pinnatifid* leaf with the points of the lateral lobes turned towards the base, as in the Dandelion. When the incisions are deep, but very irregular in size and form, the term *laciniate* is sometimes employed.

When the ribs have the palmate arrangement, similar terms are subjoined to the prefix *palmi-* or *palmati-*, or *palmifid* (fig. 94), *palmisect* (fig. 96), and *palmipartite* (fig. 95), according to the depth of the divisions. A special modification of this type occurs not unfrequently, when the lower or outer ribs, and consequently the basilar lobes, turn back more or less towards the petiole; such leaves are generally deeply cut; but the general prefix *pedati-* may be used in the words *pedatifid*, *pedatisect*, or *pedatipartite* (fig. 97), according to the rule given above. Such leaves may be compared to sympodial ramifications; the central lobe is the primary one from which on either side lobes of the second degree are formed; these produce tertiary lobes, and so on, but always on one side only, as in some forms of definite ramification.

Fig. 96.

A palmisect leaf, the segments oblong-obovate serrated.

Fig. 97.

A pedatipartite leaf, the segments lanceolate.

The *bilobed*, *trilobed*, *quinquelobed*, and similar forms are usually referable to the palmate type, and should be more definitely named if they occur in a genus where the leaves exhibit many of these forms, in a *constant* manner; if the leaves are inconstant in the depth of the divisions, these more general names are preferable.

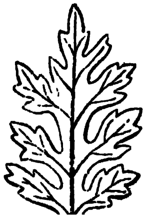
Simple leaves divided on the feathered plan exhibit also more complicated conditions. The primary lobes of a pinnately cut leaf may be subdivided again in the same manner, and the secondary lobes again into tertiary lobes. These are named on the same principles, *bipinnati-*, *tripinnati-* *-fid*, *-sect*, or *-partite*, according to the degree of division of the *last set of lobes*, *i. e.* of the secondary lobes of bipinnatifid (fig. 98) and the tertiary of tripinnatifid. When the leaves are subdivided a *fourth time*, or even where *tripinnatisect leaves have filiform segments*, the term *dissected* is usually employed.

It must be borne in mind that the terms above defined are applied in a similar manner to the leaflets of compound leaves, next to be described, being subjoined in description to the terms which define the plan and

degree of division of the petiole. They also apply to the bracts, sepals, and all other organs of a leaf-like character.

Compound leaves are such as have the petiole branched once or more times before it bears blades; the branches of the petiole are called *partial petioles* or *petiolules*, and are often articulated to the main petiole, which in this case is occasionally termed the *rachis*. Stipels occur at the bases of some partial petioles. The

Fig. 98.

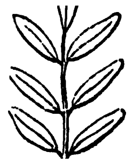


A bipinnatifid leaf.

Fig. 99.

A paripinnate leaf.

Fig. 100.



An imparipinnate leaf.

separate blades of the leaf are called *leaflets* (*foliōla*), or *pinnæ*. Compound leaves may be classed generally into simply, doubly,

Fig. 101.

Fig. 102.

Fig. 103.

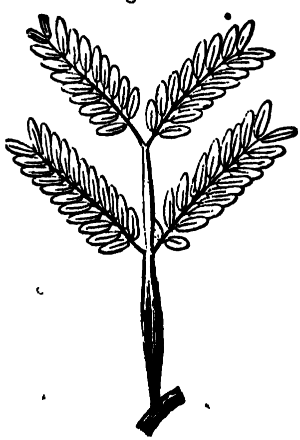
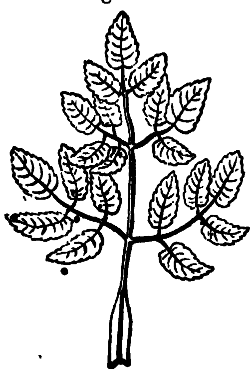


Fig. 101. A binate or unijugate pinnate leaf.
Fig. 102. A bipinnate leaf, the pinnæ unijugate.
Fig. 103. A bipinnate leaf, the multijugate pinnæ paripinnate.

triply compound or decompound (*supradecomposita*), according to the number of the successive branchings of the petiole. The ramification follows the same types as that of the ribs of simple leaves, and exhibits analogous subordinate modifications.

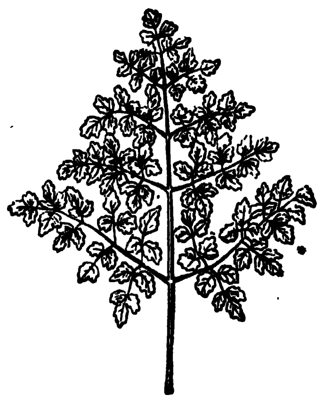
Pinnate leaves are such as have a rachis bearing sessile or stalked lateral leaflets arranged on the feathered plan. Sometimes there is an odd terminal leaflet, when the leaf is *unequally* or *impari-pinnate* (fig. 100). When there is no end leaflet, the leaf is *abruptly* or *pari-pinnate* (fig. 99). *Interruptedly pinnate* means that the opposite pairs of leaflets are alternately large and small, as in *Agrimonia*. The pairs of leaflets are sometimes called *juga*; and if only one pair exists, the leaf is *unijugate* (fig. 101); if more pairs, *multijugate*. If the leaflets are not in pairs, but alternate with each other, the leaf is *alternipinnate*.

Fig. 104.



A bipinnate leaf, the pinnæ imparipinnate.

Fig. 105.



A tripinnate leaf, the pinnæ imparipinnate.

Bipinnate leaves are formed when the main petiole bears secondary petioles with distinct leaflets pinnately arranged (figs. 102–104). *Tripinnate* leaves exhibit an additional (tertiary) series of partial petioles with distinct leaflets (fig. 105). When the division goes beyond the third degree, the leaves are called *decompound* (fig. 106); but it is more common to find bipinnate or tripinnate leaves with their leaflets pinnatifid, -partite, &c.

Palmate (or *digitate*) leaves are such as have a number of distinct leaflets arising from one point, like the ribs of a simple leaf when the plan is palminerved. *Bi-* or *tripalmate* leaves are very rare (Araliaceæ). The only modification appears to be the *pedate* leaf, analogous to the pedatisect simple leaf, but with distinct leaflets (fig. 107).

The terms *ternate*, *quinate*, and *septĕnate* are often applied to palmate leaves with a definite number of leaflets. *Ternate* leaves, however, may occur either on the palmate (fig. 108) or pinnate plan; if on the latter,

there is only one pair of lateral leaflets and a terminal one, but in these the petiole is ordinarily developed between the pair of leaflets and the

Fig. 106.

Fig. 107.

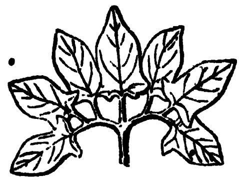


Fig. 108.

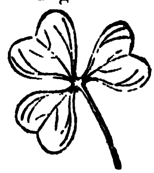


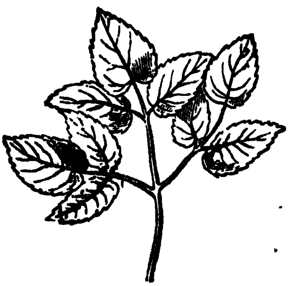
Fig. 106. A pinnately decompound leaf.
Fig. 107. A pedate leaf.

Fig. 108. A ternate leaf with obcordate leaflets.

end one. What are called *biternate* (fig. 109) and *triternate* compound leaves are in most cases *pinnate* leaves with unijugate and terminal leaflets. Such leaves should perhaps be called *ternato-pinnate* or *biternato-pinnate*, &c.

A modified form, apparently intermediate between *pinnate* and *palmate* leaves, like some *ternate* leaves, occurs through the suppression of the main rachis of the bipinnate leaves of some Acacias, giving what may be called a *palmipinnate* form (fig. 110).

Fig. 109.



A biternate leaf.

Fig. 110.

A palmipinnate leaf.

The leaflets of compound leaves of Flowering plants are ordinarily called *pinnæ*, and their subdivisions *lobes*; but in the Ferns, where the leaves are highly compound, and the segments somewhat variable in the degree of confluence, the primary divisions of the leaf are called *pinnæ*, the secondary *pinnules*, and the tertiary *lobes* or *segments*. In highly compound leaves, the ramification of the petiole and subdivision of the laminar structure become less complex toward the apex.

Texture.—The varieties of texture of ordinary leaves depend chiefly upon their anatomical condition; but it is requisite to notice here several terms, such as *membranous*, *leathery* (or *coriaceous*), *succulent*, &c., used in Descriptive Botany, but which scarcely require explanation. In aquatic plants the leaves are usually of slighter texture: when they *float* on water (*natant leaves*) the forms and general external characters are not much modified; but when they grow wholly under water (*submerged leaves*), they are not only more delicate, but are sometimes cut up into fine filiform segments, as in *Ranunculus aquatilis*.

Duration.—The duration is different in different plants. Those which are unfolded in spring and fall off in autumn are called *deciduous*. What are called *evergreen* leaves vary in duration: thus in ordinary evergreens, such as Ivy, Cherry-laurel (*Prunus Laurocerasus*), &c., the leaves remain through the winter and fall off only when the new ones are becoming developed in the spring; while in many Conifers, as in species of *Pinus*, *Araucaria*, &c., the leaves remain attached for many years.

The anatomical structure of leaves exhibits many interesting modifications, related in some degree to the media and climates in which plants grow. These will be more particularly explained in another place.

Surfaces.—The surfaces of leaves, like those of herbaceous stems, exhibit a variety of conditions dependent on the character of the epidermal layer.

Glabrescent is used to signify that a surface, hairy when young, becomes smooth when the leaf is mature, by the hairs falling off. Some smooth surfaces are *shining*; and this is very often the case with the upper surface of evergreen leaves. Hairy surfaces are differently denominated, according to the character of the hairs and their mode of occurrence. Thus a *pilose* surface is covered with scattered soft and small hairs, a *hirsute* with scattered long hairs, a *hispid* with scattered stiff hairs; while a *pubescent* surface is covered closely with short soft hairs, a *villous* closely with longish weak hairs; and when the hairs are curled and interwoven, the terms *silky* (*sericeus*), *woolly* (*lanatus*), *felted* (*tomentosus*), or *floccose*, are applied according to the coarseness of the hairs and the thickness of the coat they form.

What may be called the natural smoothness of surfaces may be interfered with by other irregularities analogous in their nature to hairs. Slight, almost invisible rigid projections render the surface *scabrous*:

hard rigid hair-like processes, called *bristles* or *setæ*, make the surface *setose*; and similar structures still more developed (occurring mostly at the apex and the points of the teeth of leaves), called *spines*, sometimes occur and produce a *spinous* surface. Modified, usually compound hairs, containing oily or resinous secretions, are called *glandular* hairs, rendering a surface *viscous* or *glutinous*, which conditions, however, are sometimes produced by *glands* sunk in the epidermis. The glands are sometimes superficial productions from the epidermis or skin of the leaf, at other times they are outgrowths from the tissue of the leaf itself, as will be described more fully when their structure is considered. *Stings* are long stiffish hairs containing an irritating fluid. *Scaly* (*lepidotus*) surfaces are produced by the occurrence of minute *stalked* flat scales, analogous in their nature to hairs. Sometimes the cuticular layer of the leaf separates in minute scale-like fragments, giving a *scurfy* appearance to the surface, which is termed *furfuraceous* (as in the leaves of the Pine-apple and its allies). The *pruinose* condition is that which results from the conversion of the cuticle into a thin detachable film of waxy matter, of which the "bloom" of plums, grapes, &c. affords an example. These structures will be more fully described under the head of Minute Anatomy.

Characters afforded by Leaves and their Modifications.—In Descriptive Botany attention is specially paid to the *situation*, *attachment*, *duration*, *direction*, *arrangement*, *form* (general and of base, apex, margins, surfaces), *nervation*, *colour*, *texture*, &c., as above described and as further illustrated in the section on the mode of describing plants. With the necessary modifications, the same directions apply to the parts of the flower, &c.

Special Modifications of the Leaf and its Parts.

Under the head of the petiole we have spoken of *phyllodia* as blade-like forms of the petiole (figs. 57 & 58). Not only does the leaf-stalk exhibit this and other modifications, disguising its real nature, but the blade also and the stipules are subject to similar modifications, in which the organ or region is only recognizable by its position and relations.

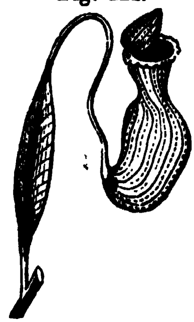
As these metamorphic structures fall under certain types, which are represented in different cases by all the different regions of the leaf, it is most convenient to describe them under special names.

Pitchers (*ascidia*) are structures of the form indicated by their name, produced by peculiar modes of development of the petiole, the blade, or of both together.

One of the best-known examples is found in the *Nepenthes*, or Pitcher-plants, in which a portion of the leaves exhibit a very long stalk, winged at the base, supporting at the extremity a pitcher-like sac of ordinary leafy texture, furnished at its mouth with a little flat plate resembling a lid (fig. 111). The pitcher is commonly explained as a kind of *phyllode*, or

foliaceous petiole, rolled up, and with its margins confluent, the lid-like body being regarded as the *lamina*; but it appears more correct to consider the pitcher as the lamina furnished with a distinct terminal lobe (*operculum*). *Sarracenia*, a North-American bog-plant, has analogous pitchers, which are sessile at the base of the flowering stem; *Heliamphora* (Guiana) has the pitchers less complete, the inner side being slit down as it were for some distance, from the imperfect confluence of the margins of the leaf. In *Dischidia Rafflesiana* the pitchers are plainly formed from the blade, and are open at the end next the petiole; and a similar condition exists in the pitchers formed from the bracts of *Marcgravia* and *Norantea*. Somewhat allied to the above, on a small scale, are the *utriculi*, or sacs of the *Utricularia* (fig. 112), little bladder-like organs, closed at first by a lid, developed from some of the lobes of the leaves of these aquatic plants, and apparently serving as "floats" and as traps for insects. In other aquatics (*Trapa*, &c.) floats are formed by *inflated petioles*, constituting as it were indehiscent pitchers, surmounted by ordinary blades.

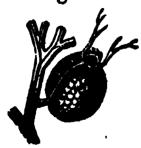
Fig. 111.



Pitcher of *Nepenthes*.

Teratological illustrations of the origin of pitchers are occasionally afforded by garden plants. This has been especially observed in the Tulip, in which the leaf next the flower-stalk has been found with its margins completely confluent into a kind of spathe, which bursts by a transverse fissure to allow the flower to appear.

Fig. 112.



Utriculus or air-sac of *Utricularia*.

Tendrils (*cirri*) are thread-like processes, curled spirally, by

Fig. 113.

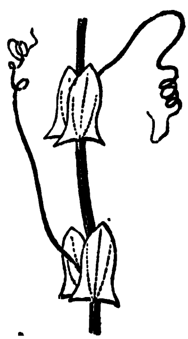


Fig. 114.

Fig. 113. Leaves of *Lathyrus Aphaca*, represented by tendrils, with large foliaceous stipules.
Fig. 114. Leaf of *Gloriosa superba*, prolonged into a tendril.

which weak-stemmed plants attach themselves to foreign bodies. They may be modifications of any part of the leaf or of a branch.

In *Lathyrus* the blade-structure of the leaf is more or less deficient in different species. In *L. Aphaca* (fig. 113) it is wholly wanting, the petiole running out into a tendril, which may be regarded as consisting either of the leaf-stalk alone, or of this and the midrib of the lamina. In *L. odoratus* (Sweet Pea) the pinnately compound leaf has one pair of leaflets, and usually one pair of tendrils, and a terminal tendril in the ordinary place of the remaining leaflet. In the edible garden Pea there are several pairs of leaflets, and often several pairs of tendrils, with a terminal one. In *Gloriosa superba*, a Liliaceous plant, the broad simple lamina runs out into a terminal tendril (fig. 114). In *Smilax* (fig. 115) the two stipules are represented by a pair of tendrils; while in the Cucurbitaceæ one tendril only occurs, which some regard as a stipule, others as a metamorphosed leaf, others, again, as a branch or peduncle.

Fig. 115.

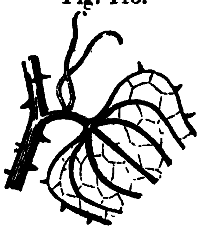


Fig. 116.

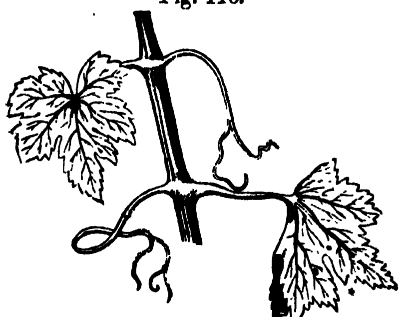


Fig. 115. Tendrils of *Smilax aspera*, formed from the stipules.
Fig. 116. Leaves and tendrils of the Vine.

The tendrils of the Vine (fig. 116) are modified flowering branches, originally terminal but displaced during growth so as to become placed opposite to leaves, and often tuberculated by the existence of abortive flower-buds. The nature of the axillary tendrils of Passion-flowers is similar.

Spines (*spinæ*) or thorns are hard, sharp-pointed woody processes, formed, like tendrils, by modification of entire organs or parts of such.

Thus in the common Berberry some of the leaves are represented by compound spines, in the axils of which arise fasciculate groups of leaves. In the False Acacia-tree (*Robinia Pseudacacia*) the stipules are represented by a pair of spines at the base of the petiole (fig. 117), while in certain species of *Astragalus* the petioles are converted into spines after the fall of their leaflets.

Fig. 117.

Base of the leaf of *Robinia*, with stipules developed as spines.

Spinous processes are developed upon the petiole in the upper part of the leaves of certain Palms (*Plectocomia*), and even on the surfaces of some leaves, as in some varieties of Holly.

True spines, however, are more frequently dependencies of the stem: thus in the Gooseberry they are developed from the *pulvinus*, below the base of the petiole. In the Black-thorn (*Prunus spinosa*) the spines are real branches (fig. 118), as also are the spines of *Gleditschia triacanthos* (fig. 119), and the principal spines of Furze (*Ulex*), in which, however, the points of the leaves are spinous also.

Fig. 118.

Fig. 119.

Fig. 118. Spinous branch of *Prunus spinosa* (Black-thorn).
Fig. 119. Spinous branch of *Gleditschia triacanthos*.

Prickles (*aculei*), properly so called, are sharp woody processes, straight or curved, occurring upon stems, leaf-stalks, at the points or on the margins, or upper surface of leaves. They are distinguished from true spines by their originating from the epidermis, like hairs, glands, &c., and by having no connexion with the internal woody substance of the stem or ribs of the leaves &c.

Glands.—This is perhaps the most convenient place to mention the nodular or discoid glandular bodies that occur in connexion with certain leaves, as on the petioles of *Passiflora* &c. They are distinct in their nature from the epidermal glands before mentioned, and considerable attention has been directed to them on morphological grounds; hence they will be adverted to again in speaking of the flower.

Sect. 5. The Leaf-bud.

The bud is a compound structure, composed of a solid conical or growing point, supporting a number of rudimentary leaves. In the *leaf-bud*, or rudiment of a shoot, the conical base represents the future stem, with its internodes as yet undeveloped; the scales are either entirely rudimentary leaves, or a portion of

them on the outside are modified leaf-structures, forming scales for the protection of the inner leaves, and destined to fall off when the bud expands. In the early conditions, the *flower-bud* is essentially analogous to a leaf-bud; but its ultimate history is different, as will be shown hereafter.

Many of the general characters of buds have been described already, under the head of the stem (pp. 34, 35); but there are some other more special peculiarities which require separate treatment here; and repetition of certain more important facts will not be disadvantageous.

In all seeds, except those of the few Orders which present an incomplete or acotyledonous embryo, the young plant is possessed, at or soon after the time of germination, of a rudimentary bud, called the *plumule*, situated at the point of growth of its ascending axis (figs. 120–122). This is the *terminal bud* of the young

Fig. 120.

Fig. 121.

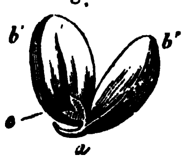


Fig. 122.

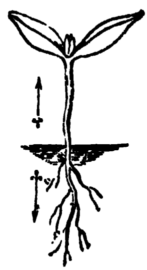


Fig. 120. Monocotyledonous embryo of *Potamogeton*, cut through perpendicularly: *a*, radicle; *b*, cotyledon; *c*, plumule.
Fig. 121. Dicotyledonous embryo of the Bean (*Faba*), with the cotyledons, *b' b'*, separated: *a*, radicle; *c*, plumule.
Fig. 122. Diagram of a germinating Dicotyledon, with the plumule or terminal bud between the expanded cotyledons.

plant; and stems and shoots only retain the power of elongating so long as they possess such a bud at their extremity. When it is removed by artificial means, by frost, or, by metamorphosis, is replaced by a flower, the onward growth of the shoot ceases.

Axillary buds are the origin of the ramifications of stems. They are developed in the *axils* of leaves; and as they unfold into secondary axes, they become the terminal buds of such shoots. Other axillary buds are formed at the nodes of these secondary shoots, to repeat the ramification by developing into tertiary axes according to the type of the species (see p. 34).

Adventitious or **accidental buds** are those which appear, contrary to the usual order, at indefinite points, unconnected with the axils of leaves. Generally speaking they are abnormal products,

presenting themselves under special conditions. They usually occur on organs in a very active state of vitality, subjected to stimulating external conditions, especially where, through natural or artificial operations, there is an absence or insufficiency of normal buds to carry off the developmental energy of the plant or organ.

Adventitious buds may be produced from any part of the plant. With regard to those produced on old stems, as in pollarded trees, or those which occur on subterraneous stolons, as in the Rose, Ash, &c., it is not always easy to decide without dissection whether the buds are really adventitious or merely latent axillary buds stimulated into development; but true adventitious buds do occur. The production of adventitious buds on true roots has been frequently observed, as in *Pyrus japonica*, *Maclura aurantiaca*, *Paulownia imperialis*, &c.; and the *Anemone japonica* is commonly propagated by cuttings of the root. The formation of adventitious buds on leaves is a still more remarkable physiological phenomenon. It has been observed chiefly in succulent leaves, but it is not exclusively confined to them. When it takes place, the first sign of development is the production of adventitious roots, followed by the formation of a cellular nodule which subsequently assumes the character of a bud. Among natural examples, the leaves of *Cardamine pratensis* have been observed to form adventitious roots on the lower side when lying upon wet ground, and even to produce buds; the leaves of several Ferns, such as *Woodwardia radicans*, root at the end, and produce buds which propagate the plant; and many similar instances might be cited. Artificial production of buds on leaves is now a familiar fact, under the influence of heat and moisture, not only on the scales of bulbs, but on the green leaves or even fragments of the leaves of *Bryophyllum*, *Echeveria*, *Gloxinia*, *Gesnera*, *Hoya*, &c.; the *Orange* and the *Aucuba japonica* may also be propagated by their leaves. Sometimes the leaves produce rootlets alone, and remain stationary without having force enough to develop a bud.

The formation of adventitious buds on leaves, especially in *Bryophyllum*, where a number are often produced, arranged on the margin, is of great interest in connexion with the theories of the structure of ovaries and the origin of the ovules.

Bud-scales.—The bud which continues the growth from the plumule of a germinating plant (fig. 122), and the axillary buds produced during a season of active growth, are composed of rudimentary leaves; but the winter- or resting buds formed on most deciduous trees and shrubs of temperate climates present the modified foliar organs called *bud-scales* (*perulæ*), analogous to the scales of bulbs and other subterraneous buds of herbaceous plants (figs. 123 and 124). Buds without scales are called *naked*. The *scales*, when present, are mostly of leathery or membranous texture, and are often clothed more or less densely with hairs, which are sometimes glandular and produce a resinous or glutinous secretion, which exudes when the buds swell.

When winter-buds swell and open, throwing off their scales, the internodes between the latter do not elongate, while those between the nascent leaves do; consequently the starting-point of each annual period of growth of a branch with an indefinitely developed terminal bud is indicated by a little band of scars marking the place where the scales stood.

Fig. 123.

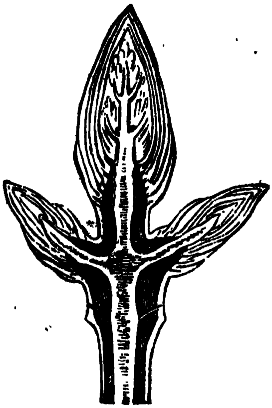


Fig. 124.

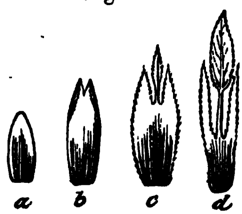


Fig. 123. Section of the end of a shoot of the Horse-chestnut, showing the terminal and two axillary buds; the terminal bud contains an inflorescence, surrounded by scales and rudimentary leaves.
Fig. 124. Bud-scales *a*, *b*, and rudimentary leaves *c*, *d*, from the winter-bud of *Prunus Avium*.

The first two scales of a bud of a dicotyledonous plant, like the two cotyledons of the embryo, usually stand right and left of the axil on which the bud arises; the succeeding scales assume at once the regular character of arrangement of the leaves of the species.

In winter-buds there is commonly a gradual transition from the pure scale to the true leaf (fig. 124), as occurs in bulbs; and the scales, as in bulbs, are referable chiefly to the vaginal or petiolar portion of the leaf. But the scales originate differently in different cases: thus we have *petiolar scales*, as in the Walnut and Horse-chestnut; *stipular scales*, as in the Vine, Oaks, Elm, Poplars, &c.; in this case, however, especially in the outer scales, the stipules and the petiole are confluent into one organ (*Prunus*, *Rosa*, &c.) (fig. 124). *Foliaceous scales* are formed by the blade of the leaf, of which we have examples in the Lilac, Maples, Coniferæ, &c.

Vernation.—The mode in which rudimentary leaves are arranged in leaf-buds is called the vernation, and furnishes important systematic characters. Two points have to be regarded here, viz.:—1, the arrangement of the leaves in relation to each other; and,

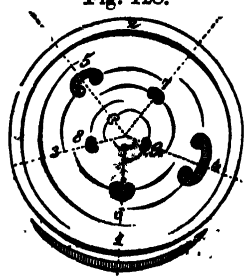
2, the manner in which each separate leaf is folded. The general arrangement is called *imbricate* or *valvate*, according as the margins of the leaves overlap one another or simply meet without overlapping; but more minute distinctions are observed, and these depend to a great extent on the phyllotaxis of the species. Thus with the $\frac{1}{3}$, $\frac{2}{5}$, or other spiral plan, we have usually triquetrous (fig. 126) or quincuncial (fig. 128) *imbricate* buds proper; with alternate $\frac{1}{2}$ or distichous leaves the vernation may be *equitant* (fig. 125), where each leaf, sharply folded (*conduplicate*), completely

Fig. 125.

Fig. 126.

Fig. 127.

Fig. 128.



Sections through Buds, showing their reciprocal vernation.
Fig. 125. Imbricated, and equitant (of a Grass).
Fig. 126. Imbricated, triquetrous (of a Carex).
Fig. 127. Induplicate, decussate (of the Apple).
Fig. 128. Imbricated, quincuncial (of a Poplar).

embraces its successor (as in the Flag), or *half-equitant* or *obvolute*, where the leaves are similarly folded, but each leaf embraces only one (lateral) half of the blade of its successor. *Valvate* buds occur mostly where the leaves are opposite; a modification of this form exists where the margins of the leaves are rolled inwards (fig. 127), and is called *induplicate vernation.*

The individual leaves in a bud are either *flat*, *folded*, or *rolled*. For the first, of course, no special term is requisite. Of the folded leaves we have:—*reclinate*, or inflexed, where the leaf is folded horizontally, so that the point is brought down to the base (*Liriodendron*); *conduplicate* (fig. 125), where the leaf is folded perpendicularly at the

Fig. 129.

Fig. 130.

Fig. 131.

Sections through leaves showing their individual vernation.
Fig. 129. Vernation of a plicate leaf.
Fig. 130. Vernation of a convolute leaf.
Fig. 131. Vernation of revolute leaves.

midrib and the lateral halves are placed face to face (Oak); and *plicate* (fig. 129), where the blade exhibits several perpendicular folds, as in a fan (Vine, Beech, Maple, Currant, &c.); this last is often combined with the preceding. When rolled up, also, the rolling may take place in either direction: where the apex of the leaf is rolled down toward the base, as in the Ferns and in the flower-stalk of *Drosera*, it is *circinate*; if the leaf is rolled up from side to side like a plan, with only one edge free, as in the Cherry &c., it is *convolute* (fig. 130); when both margins are rolled inward toward the midrib, it is *involute* (fig. 127); and when both margins are rolled outward toward the midrib, it is *revolute* (fig. 131).

Sect. 6. The Inflorescence.

In all Flowering Plants, a portion of the buds change their character at certain periods and in certain situations. They cease to elongate and produce true leaves, while the foliaceous organs of which they are composed are gradually developed into that assemblage of organs which constitutes a flower.

So intimately are the leaf-bud and flower-bud related, that, under peculiar conditions, producing monstrous growths, flower-buds are seen to expand into tufts of green leaves, or imperfect flowers to throw out leafy shoots from their centres; such cases are often observed, for instance, in cultivated Roses; and leaf-shoots may likewise exhibit more or less of the characteristics of a flower, &c.

Flower-buds are subject to the same laws of arrangement as leaf-buds. The buds which commence the growth of the reproductive structures may be at once developed into solitary flowers, or, as is more common, the blossom-buds unfold into a system of branches terminating in flowers, the branches all originating in the axils of modified leaves, called *bracts*. The solitary flower, or the connected system of flowers arising from one point, is called the *inflorescence*, which is either *terminal* or *axillary*.

The inflorescence is produced from the terminal bud, or from this and one or more of the upper axillary buds, in most annual plants; and there is often a gradual transition from the true-leaf stem into the bract-region, or inflorescence. The same is the case, to a great extent, with the flowering stems of biennials. The inflorescence of herbaceous perennials, bulbs, &c. is either terminal or axillary, as is that of arborescent plants. In the Horse-chestnut (fig. 123) and Lilac, for example, the terminal bud usually ends in a blossom, while in the Apple and its allies the inflorescence is axillary.

When the inflorescence is developed from the terminal bud of an unbranched stem, the growth of the plant ends in the blossoming, as is the

case in the *Agave*, the Talipot and other Palms, which require a number of years to bring them to the point of flowering, after which they die away, like a bulb with a terminal inflorescence, the plant being sometimes propagated at the same time by offsets from the axils of the lower leaves. The inflorescence of other unbranched Palms, such as the Cocoa-nut, is axillary, and thus may be repeated indefinitely.

A flower-bud may be either *sessile* or *stalked*; if the latter, the stalk is called the *peduncle*. The branches of the peduncle or the slender stalks bearing the individual flowers are called *pedicels*, and that portion of the main flower-stalk or axis from which the pedicels spring is sometimes called the *rachis*.

Solitary flowers.—The simplest forms of inflorescence consist of solitary flowers, either terminal (as in the Tulip), or axillary, when simple peduncles arise from the axils of ordinary leaves (as in *Lysimachia Nummularia*, see also fig. 13, p. 23).

The term *scape* (*scapus*) is applied to a stem devoid of true leaves, arising underground from the terminal bud or from the axil of a scale or leaf of a rhizome, bulb, &c. It may bear a single flower, as in the Tulip, or a group of flowers, as in the Hyacinth, or a "head" of flowers, as in the Daisy, Dandelion, &c.

When solitary flowers arise in the axils of ordinary leaves, the flower-leaf or bract-region of the stem is scarcely represented (fig. 13), or, at least, does not differ from the true-leaf region; but, generally speaking, those parts of the stem which bear flowers are separated to a certain extent from the true-leaf region, and form a distinct association of parts, representing the bract-region. In the flowering stems of annuals and biennials it is often difficult to draw a line at the boundary of the true-leaf region and the inflorescence, from the leaves passing insensibly into bracts from below upwards, as in the Foxglove.

Bracts.—The leaves of the flower-leaf region of the stem are called bracts. They are mostly smaller than the leaves preceding them, usually simple, and often scale-like, or *glumaceous*, consisting of the vaginal portion of the leaf only. In the generality of cases they are green; but not unfrequently they are tinged with the same colours as flowers (as in various Sages), or are even entirely petaloid. In other cases they are membranous, and then often very transient in their existence. The diminutive term *bracteole* is applied to the small bracts which occur on the pedicels of certain plants, often in pairs.

The term *bracteole* is loosely applied by some authors to the smaller bracts of a compound inflorescence; but it is much more convenient to use the term *bract* for all leaves which subtend branches of the inflorescence, and to call those scales *bracteoles* which occur on an ultimate pedicel, as in many Leguminosæ. In Monocotyledons there is usually

a single bracteole, while in many Dicotyledons there are two; in the former case the anterior surface of the bracteole is directed towards the primary axis from which the flower is produced, in the latter the two bracteoles are lateral or oblique to the axis.

As a general rule, all ramifications of inflorescence arise in the axils of bracts; but the bracts are sometimes regularly abortive, as in the Cruciferæ. On the other hand, we sometimes find the lower part of the inflorescence crowded with bracts with empty axils.

Spathe.—In many plants the bract subtending the whole inflorescence or its principal branches is large, and forms a kind of sheath, called a *spathe.* Sometimes this surrounds only one flower, as in some Daffodils, &c., where it is of membranous texture; the membranous spathe of the Onion and its allies encloses a dense inflorescence; in the Araceæ (fig. 133) it is still more developed, and sometimes of petaloid structure, as in the so-called Trumpet-lily (*Richardia æthiopica*), where it encloses the club-like inflorescence; while in the Palms (fig. 134) it assumes enormous dimensions and a leaf-like or even fibrous texture, forming a sheath to a large and greatly ramified inflorescence.

Involucre.—In other cases, several bracts are collected together, forming a whorl or densely packed spire, called an involucre. The Umbelliferæ have frequently verticillate involucres at the base of the umbels, and sometimes secondary whorls or *involucels* at the base of the secondary umbels (fig. 140). In the Compositæ also, where the flowers are crowded on a common receptacle, the bracts form an involucre (figs. 141–146); smaller scale-like bracts occurring among the florets of these capitula are called *paleæ* (figs. 145 & 146). Other examples of involucre are furnished by the *cupules* of the Oak, Beech, Filbert, &c., wherein the bracts are united or not disconnected at the base; also by the outer *glumes* or scales of the spikelets of Grasses.

Forms of Inflorescence.—The different forms of the Inflorescence are divisible into two classes:—1, the *indefinite*, where the terminal bud of the main or primary axis does not form a flower, the flowers being borne on *secondary lateral* branches, which are as a rule smaller and weaker than the main axis; and, 2, the *definite*, where the *primary* axes either bear *terminal* flower-buds, while the succeeding flowers spring from *secondary axillary* branches produced lower down, and subsequently to the terminal bud, or branch in a forked manner without producing a flower in the centre of the fork. The secondary branches are here as strong or stronger than the main axis. The forking is not neces-

sarily a true dichotomy, but may apparently be so owing to the abortion of the terminal bud.

Examples of the indefinite form are seen in the Cruciferæ, especially the Wallflower, where a few flowers at first appear in a tuft, while the seed-vessels are afterwards wide apart on an elongated raceme, the uppermost being the youngest. In the Foxglove and similar plants we may produce a very long development of the indefinite structure by picking off the lower flowers as they wither, when, as no seed is formed, the indefinite terminal bud retains its energy, and continues to lengthen until the plant is exhausted. On the other hand we observe, in the Sweet-William, the Elder, and the Hydrangea, the centre flower of a tuft opens first, and the *definite* inflorescence becomes wider and wider, but never elongates or grows out in the centre.

Fig. 132.

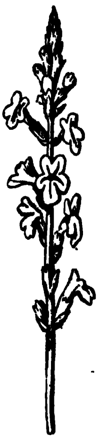


Fig. 133.

Fig. 134.

Fig. 135.

Fig. 132. Spike of *Verbena officinalis.*
Fig. 133. Spadix and spathe of *Calla.*
Fig. 134. Compound spadix and spathe of a Palm.
Fig. 135. Compound spike, with spikelets, of *Lolium.*

When an *indefinite* inflorescence is elongated the lowermost flowers open first, while if it be of a flat-topped or crowded character, the outermost flowers open first and the central ones last, as in the capitula of the Compositæ. Hence the indefinite forms of inflorescence are sometimes called *centripĕtal* or *progressive,* and the definite *centrifŭgal* or *regressive.*

There is an exception to the ordinary regularity in the capitula of *Dipsacus* (Teazel), where the florets open first halfway up, and then proceed both centripetally and centrifugally.

Forms of Indefinite Inflorescence.—Of the Indefinite Inflorescence the following are the most important forms :—the *spike*, the *raceme*, the *corymb*, the *umbel*, and the *capitulum*.

Spike.—The spike is a long simple axis or *rachis* bearing sessile flowers, either standing at intervals, as in the Vervain (fig. 132), or crowded, as in the common Plantain and many Sedges.

Several modifications of the spike have distinct names. When the rachis bears large, persistent, imbricated bract-scales, it forms a *cone* or *strobile*, as in the Firs and Pines. When it is thick and fleshy, with the flowers more or less imbedded in it, the term *spadix* is applied, of which the Araceæ furnish examples (fig. 133) ; the same term is conveniently retained when this fleshy axis is branched, as in the Palms (fig. 134). The so-called spikes of many Grasses, such as Wheat, Barley, Rye-grass (fig. 135), Cat's-tail-grass, &c., are also compound spikes, since in place of single flowers the rachis bears *spikelets* or short axes with several sessile flowers. The term *catkin* (*amentum*) is applied to the pendent, often caducous, spike-like inflorescence of the Willow, Poplar, Birch (fig. 136), and the male inflorescence of the Oak, Filbert, Chestnut, &c. ; in these the bracts have sometimes *one*, sometimes *several* flowers in their axils. The flowers in catkins are usually unisexual.

Fig. 136.

Male and female catkins of the Birch.

Raceme.—The raceme differs from the spike in having the flowers distinctly stalked, the main rachis being unbranched, as in the Hyacinth, &c.

Corymb.—The corymb is formed when the flowers originate as in the raceme, but the lower ones are raised on longer stalks than the upper ones, so as to bring them all nearly on a level, as in *Ornithogalum* (fig. 137), &c.

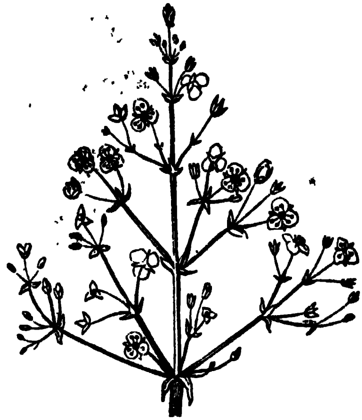
As already noticed, a corymbose inflorescence sometimes grows out into a raceme while the fruits are ripening, as is seen in many Cruciferæ. The relation between the two forms, or, more properly, between the panicled and the corymbose state of the same inflorescence, is well seen in comparing a Cauliflower as fit for the table with the expanded inflorescence of the same plant when allowed to run to seed.

Panicle.—A panicle is formed when the main rachis is more or less branched ; it is hence a series of racemes on a branched rachis. The term *panicled* is often used in a general sense, to signify a much-branched inflorescence, whether definite or indefinite.

Fig. 137.

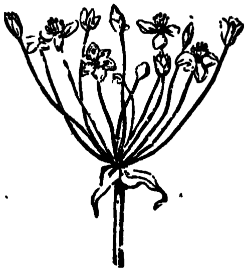
Corymb of *Ornithogalum.*

Fig. 138.



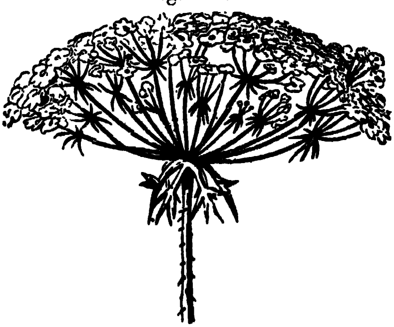
Panicled cyme of *Alisma Plantago.*

Fig. 139.



Umbellate inflorescence of *Butomus umbellatus.*

Fig. 140.



Compound umbel of the Carrot.

Umbel.—The *umbel* is formed by a number of single flowers borne on long stalks of nearly equal length arising from one point, as in the common Cherry, the Cowslip, &c. In the family of Umbelliferæ, so called from the prevalence of this inflorescence, the umbels are mostly *compound* (fig. 140); that is, the first set of peduncles do not bear flowers, but secondary sets of radiating branches, forming *umbellules*, or secondary umbels. Inflorescences of this general character are termed *umbellate* even when definite.

Umbels usually have an involucre at the base of the radii, as noted above. The simple umbels of the Onion group are originally enclosed in a membranous spathe.

Capitulum or Head.—The capitulum is mostly formed by the rachis expanding into a thickened mass, surrounded by an involucre of overlapping bracts, presenting a convex, flat, or concave surface (*common receptacle*), upon which are crowded a great number of sessile flowers, as in the families of Compositæ and Dipsaceæ (figs. 141–146). In the Compositæ there are often little mem-

Fig. 141.

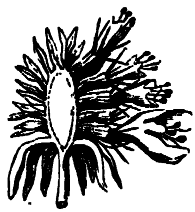

Fig. 142.


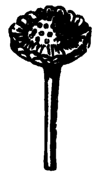
Fig. 143.


Fig. 144.


Fig. 141. Capitulum of *Scabiosa*.
Fig. 142. Vertical section of the capitulum of *Scabiosa*.
Fig. 143. Receptacle of the Daisy with the florets removed.
Fig. 144. Receptacle of Dandelion with the florets removed; bracts of the involucre reflexed.

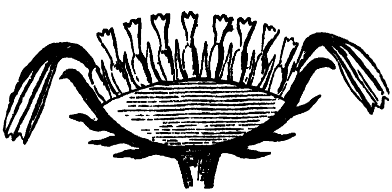
Fig. 145.


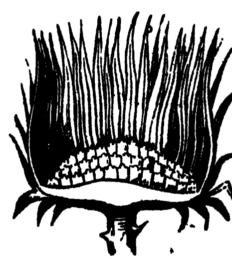
Fig. 146.


Fig. 145. Section of a capitulum of a Composite plant with paleæ at the base of the central tubular and of the marginal ligulate florets.
Fig. 146. Section of an empty capitulum of a Composite plant with a paleaceous receptacle.

branous bracts (*paleæ*) at the outside of each flower (figs. 145, 146); in the Dipsaceæ each flower is surrounded by a cup-like involucel (fig. 142).

The flowers crowded together in the capitula of Compositæ are small and of various forms, so arranged as to give the whole the outward aspect of a single flower; hence this inflorescence was formerly called a *compound flower*, and its involucre a *common calyx*.

The flowers in the capitula of the Compositæ are called *florets*; and different names are applied to this inflorescence, according to the mode of arrangement of the florets. In the Daisy, we observe a yellow middle *disk* and a white or pinkish *ray*; the *disk* is composed of florets different in character from the spreading florets of the *ray* (fig. 145). Some capitula are wholly *discoid*, such as those of Groundsel (*Senecio vulgaris*), of Thistle, &c.; others are wholly *radiant*, such as those of the Dandelion, Lettuce, &c.

It should be observed that cultivation tends to convert tubular florets into spreading ones, and so to obliterate the yellow disk or "eye," as we observe in the Dahlia, garden Daisy, &c.

Capitula of less marked character are found in other families, where, however, the involucre is wanting; for example, the flowers of Clover (*Trifolium*) have a capitular arrangement, as also those of many Proteaceous plants (*Banksia*). In the Fig the peduncle or common receptacle is fleshy and excavated (fig. 147), the flowers being inside and developed centrifugally; in *Dorstenia* (fig. 148) the receptacle is flat or slightly concave on the top, while in *Artocarpus* and other cases the flowers are on the outside of a convex peduncle. These forms of inflorescence are only slight modifications of the *capitulum*. Such inflorescences must not be confounded with the concave top of the flower-stalk enclosing the carpels of a single flower, as in the Rose.

Fig. 147.

Fig. 148.

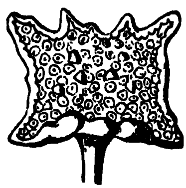


Fig. 149.

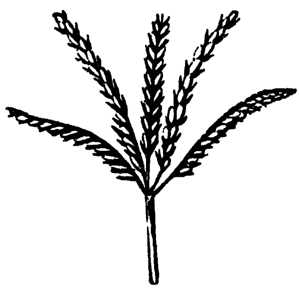
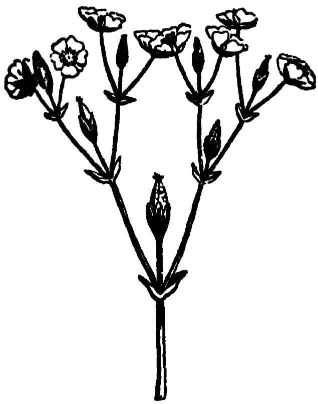


Fig. 147. Inflorescence of the Fig; the flowers inside the excavated fleshy receptacle.
Fig. 148. Inflorescence of *Dorstenia*; the flowers imbedded in the fleshy receptacle.
Fig. 149. Compound umbellate spike inflorescence of *Digitaria*.

Forms of Definite Inflorescence.—The forms of definite inflorescence are also termed *cymose*, the term *cyme* (fig. 150) being very general in its application; for it is used in reference to a

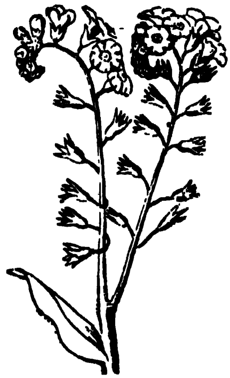
number of forms more or less resembling outwardly the raceme, corymb, and others of the indefinite type, but all agreeing in

Fig. 150.



Dichasium or dichasial cyme of *Cerastium*.

Fig. 151.



Scorpioid cyme of *Myosotis palustris*.

producing a primary terminal flower on each shoot, and continuing the subsequent evolution by secondary axillary development, the development of the lateral shoots being thus more vigorous than that of the primary shoot.

The loose cymose inflorescence of many Caryophyllaceæ illustrates the *definite* mode of growth very clearly; the primary axis terminates in a flower (figs. 150, 152), then branches arise in the axils of a pair of bracts lower down; these branches repeat the process, and their branches again, until the flowering shoot is exhausted.

Cymose inflorescences admit of division into two principal groups, according as they are *monopodial* or *sympodial* (see *ante*, p. 39).

Monopodial Cymes.—Each branch of the inflorescence is here terminated by a primary flower (fig. 152, I), below which are developed two or more secondary flower-stalks, one on each side, and each in its turn surmounted by a flower (fig. 152, II, III, IV). The simplest form of this is the *dichasium* (figs. 150, 152), the *cyme bipare* of the French. There is no true *dichotomy* in such instances, the appearance of such being due to the superior development of the side branches as compared with that of the terminal one.

Sympodial Cymes.—These may be called unilateral, as in them the secondary branches of the same degree are developed on one side

only: thus the primary flower-stalk or axis ends in a flower: beneath this arise not two branches, one on either side, as in a dichasium, but one only, this one being terminated by a flower like the primary branch and giving off a tertiary branch as before (fig. 153). The flower-stalks here appear to be opposite to the

Fig. 152.

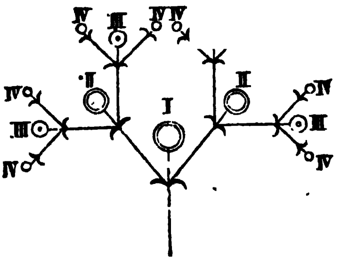


Fig. 153.

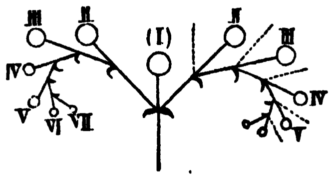
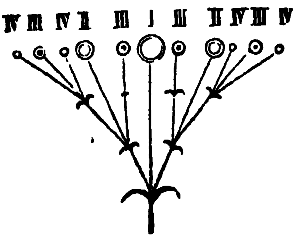


Fig. 154.



Figs. 152–154. Diagrams illustrating the centrifugal development of cymose inflorescences. Fig. 152 a globose dichasial cyme; fig. 153 a sympodial scorpioid cyme, the dotted lines indicate the suppressed branches; fig. 154 a corymbose cyme. One of the lateral branches at III is abortive.

bracts; but the bract in this case belongs not to the flower-stalk immediately opposite to it, which is a primary formation, but to the secondary flower-stalk which springs from its axil.

The subsidiary flower-stalks are sometimes developed all on the same side when the inflorescence becomes curled from the greater growth on one side than on the other. Such cymes are called *scorpioid cymes* (fig. 151). At other times the subsidiary pedicels or flower-stalks are developed alternately, first on one side and then on the other, when the inflorescence has a zigzag shape. When the main rachis is a sympode (p. 39), and the flowers, instead of being all on one or on two opposite sides, are disposed spirally, the term *helicoid cyme* is given. In these forms of cyme one of a pair of peduncles is generally systematically suppressed, and this happens successively on one side of the main rachis of the inflorescence, or,

as has been said, alternately, now on this side, now on that. This main rachis is therefore not formed by one continuously growing shoot, but by a succession of shoots of different generations placed one over the other in definite order, thus forming a *sympode* (see *ante*, p. 39). In this manner we may have *spicate* or *racemose sympodial cymes* closely resembling, on a superficial inspection, spikes or racemes. If the bracts are present the true nature of the inflorescence is apparent, because in that case the peduncles are on the *opposite side of the axis to the bracts*, as in *Helianthemum*. It often happens, however, in these cases that the bracts are wholly wanting, as in Boraginaceæ, in which the scorpioid cyme has been attributed to repeated forking of the growing point; but the sympodial theory is the more probable.

Forms of Cymes.—The form of the cyme is sometimes further indicated by such terms as a *globose cyme*, a *linear cyme*, and so on. When the flowers are nearly sessile, forming a dense flat-topped bunch, such as we see in the Sweet-William and other species of *Dianthus*, the term *fasciculus* is sometimes used. Where a cymose tuft of only a few flowers, crowded together in this way, occurs in the axil of an ordinary leaf, the inflorescence is sometimes called a *glomerulus*, as in many of the Labiatæ.

Compound Inflorescence.—Some plants, especially herbaceous perennials, have *compound inflorescence*, wherein the flowering region of the stem appears to be composed of a number of distinct inflorescences arranged on a regular plan. The plan of the ramification of the main axis may be the same as that of the individual inflorescence, as in the Umbelliferæ, where both the primary and the secondary umbels unfold centripetally; sometimes the separate inflorescences are arranged in a different form belonging to the same class, as in the case of the umbellate collection of spikes in certain Grasses (*Digitaria*, fig. 149), &c.

Mixed Inflorescence.—In other cases there is a mixed condition, since in many Compositæ the individual capitula are centripetally developed, while they succeed one another on the main stem in a centrifugal or cymose order; in the Labiatæ the cymose axillary glomerules (which, occurring opposite to each other, form *verticillasters* or false whorls) are developed from below upwards, the main stem being indefinite, and they are often crowded together above so as to form a kind of compound spike.

The general facts of the morphology of the different forms of inflorescence are thus seen to be conformable to the laws ruling the development and ramification of the stem, as already explained.

The different modes of inflorescences often pass one into the other, and such inflorescence as scorpioid cymes may originate either in the manner above described, or, very rarely, by direct forking of the growing point [Warming]. The difference between a dichotomy of the growing point

and lateral ramification is not fundamental; and, again, where true dichotomy exists it is rare for the two divisions to be developed in the same manner. In some scorpioid cymes one division becomes a flower-bud, the other repeats the ramification of the axis.

Modifications of the Inflorescence.—In certain cases we have the normal condition of the inflorescence greatly disguised, as in *foliaceous peduncles*, and in cases of what is called *fasciation*, as also where the flower-stalks are apparently removed from their usual place by adhesion of various kinds and degrees.

In many kinds of *Cactus*, as already noticed (p. 38), the stem assumes more or less the outward aspect of a leaf; and when a flower springs from such a stem, it looks like an abnormal growth; but it is really produced from the terminal or axillary bud of an abortive branch. In the Butcher's-broom (*Ruscus*, fig. 155) the single branches or peduncles are flat leaf-like plates, and bear the flowers in the axils of little scales or reduced leaves which arise on the upper surface, seemingly from the midrib of a leaf; but these *foliaceous peduncles* grow from the axils of scale-like leaves (fig. 155 *). In *Xylophylla* (fig. 156) we find a *compound foliaceous peduncle*, consisting of a large leaf-like branch bearing numerous flowers on its margins, arising there in the axils of bracts.

Fig. 155.

Fig. 156.

Fig. 155. Foliaceous peduncles of *Ruscus aculeatus*.
Fig. 156. Foliaceous flowering branch of *Xylophylla*.

Fasciation is usually an abnormal condition, consisting of the development of a large number of buds in close approximation, and the consequent congenital fusion of a number of peduncles (or in some cases leafy shoots) into a solid mass, bearing the flowers on the borders. It produces the crest-like condition of the flower-stalk of the garden Cockscomb; and converts a paniculate inflorescence into a ribbon-like axis.

Adhesion, or want of separation of the peduncle from the leaf or bract, produces an appearance as if the flower sprang from the latter, as in the case of the Lime-tree. A similar union or, rather, lack of separation between the flower-stalk and the branch, the former being in such cases often raised above its normal level by the growth of the latter, produces *extraaxillary* inflorescence, as in some species of *Solanum*. Where the inflorescence is placed *opposite to a leaf*, as in the case of the Vine, &c., the inflorescence is in reality terminal (as may readily be seen in the young state); but as growth goes on it bends downwards into nearly a horizontal position, while the axillary bud next beneath it deve-

lops into a shoot which assumes a vertical direction, thus occupying the position of the inflorescence. Such branches are called by French botanists usurping branches. In a few cases absolute *partition of the growing point* has been observed—one division forming a tendril or an inflorescence, the other forming a new vegetative axis, as in *Vitis vulpina* observed by Warming.

Duration.—The inflorescence, like the leaf, varies in its duration. The staminal catkins of the Amentaceæ, such as the Oak, Hazel, Poplar, &c., fall off as soon as the pollen is discharged from the stamens, and they are called *caducous*. In many cases the inflorescence, or the individual peduncles, separate by a disarticulation when the fruit is ripe, as in the Apple, Cherry, &c.; the term *deciduous* is then applied. In the Rose we observe the dried-up fruit long remaining, like the cones of Firs, &c., after the seeds have become matured; these are *persistent*. Sometimes the peduncles undergo expansion during the ripening of the seeds, so as to form part of the fruit; such an inflorescence or peduncle is called *excrescent*. The Fig, the Pine-apple, and other fruits are formed of *excrescent inflorescences*; the Cashew-nut (*Anacardium*) has an *excrescent peduncle*.

Characters afforded by the Inflorescence.—For descriptive purposes the inflorescence must be treated as the ramifications of the stem, noting also the number of the flowers, their mode of expansion, and other peculiarities as explained in the foregoing sections.

Sect. 7. The Flower.

The Flower, the characteristic reproductive apparatus of the higher plants, consists of no new elements superadded to the fundamental organs of the vegetative regions, but is merely an assemblage of these organs modified in certain essential particulars so as to fit them for exercising new functions. A flower is a modified shoot, in which the internodes of the stem are seldom developed; while the leaves, arranged according to the general phyllotactic laws, are more or less different in form and texture, and have part of their tissues developed into more highly specialized products, distinguished both in anatomical and physiological characters from those associated with vegetative leaves.

The theory of the construction of the flower rests upon proofs derived from various sources, such as *teratology*, or the study of exceptional growths. The strongest confirmation of the views arising out of the observation of such cases is obtained by *comparative morphology*, by the *internal structure*, and by the *investigation of progressive development*, or "*organogeny*," which latter supplies a clue to the original ancestral form.

We may, in the first place, remark upon what is taught by the study of development. Flowers are common in which the organs stand in regular circles, and in which the organs of each circle agree in colour, size, and so on; but in many cases we find deviation from this regularity: the arrangement of the organs becomes changed, and the parts of particular circles become more or less different among themselves—as, for example, in the flowers of the Pea-tribe, of Labiatæ, &c. But when we examine the buds of these flowers in a very young state, we often, but not always, find the rudimentary organs regularly arranged, and, while in the state of cellular papillæ, agreeing exactly in all external characters. The subsequent irregularity is a result of special growth, for a special purpose, at a later epoch. In didynamous stamens, for example, the longer pair do not exceed the others until a late period of their development.

Transitional Forms.—The original uniformity and homogeneity of the organs of flowers are not always so completely lost in the maturation of the structures, that the different secondary types of organs, sepals, petals, &c. become entirely distinct. The study of comparative morphology reveals many cases of transition from one kind of organ to another, illustrating, in a very interesting manner, the doctrines of morphology.

In *Calycanthus floridus* and the Camellia the numerous pieces of the floral envelopes present a spiral arrangement, and it is impossible to find a distinct line of demarcation between the bracts, the calyx, and the corolla. In species of *Cornus* and *Euphorbia*, the coloured bracts of the involucre assume quite the aspect of a coloured calyx or corolla. In the White Water-lily (*Nymphæa*), a transition between sepals and petals is seen in the segments of the calyx, which are green outside and petaloid internally, while we have perfectly petaloid sepals in many flowers, as in Aconites, Larkspurs, &c., and particularly in the showy bulbous Monocotyledons commonly cultivated, *e. g.* the Lily (*Lilium*), Tulip, Crocus, &c.

In the Water-lily (*Nymphæa*) we observe a gradual transition between petals and stamens, the latter appearing first as petaloid plates, with anther-structure on the edges. In *Canna* it is the ordinary rule for the stamen to be a kind of petal bearing an anther-lobe on one upper edge. A more or less expanded petaloid state of the filament is not unusual, and in the Mistletoe the stamens are flat, leafy organs, with the pollen developed in the parenchyma of the inner face.

The stamens and pistils being so diametrically opposed in their physiological characters, we naturally do not expect to find any transition between these organs in normal flowers, though in monstrous developments such transitions are frequent.

Teratology.—The study of Teratology, the interpretation of exceptional growths by reference to laws of development more or less interfered with by external agency, is very instructive in regard to Morphology. In the exceptional products of nature or, still more, of art, we find illustrations of almost every possible kind of the general proposition above mentioned.

Phyllody.—Cases are not unfrequently observed where the entire flower is replaced by a fascicle of green leaves, especially in the Alpine Strawberry. In wet seasons it is not uncommon to find flowers of the

White Clover with more or fewer of the organs modified in this way, the pistil, one or more of the stamens, &c. appearing in the form of green leaves, occasionally compound and ternate, as on the stem below. In the Double Cherry of gardens, the place of the pistil is often occupied by a pair of green leaves; in the *Fraxinella* a circle of green leaves has been observed in the place of the ovary.

Substitution and Metamorphoses.—Almost all polypetalous flowers, and many gamopetalous, are capable of being "doubled" by cultivation, that is to say, the number of petals may be increased at the expense of the stamens, or of those and the pistils. For example, the Wild Rose has but five petals, and many stamens and pistils, but in our garden Roses the numerous stamens and pistils are often altogether replaced by petals. In many cases intermediately formed structures exist in such *double flowers*: in the double early Tulip, for example, we almost always find monstrous organs, half-petal and half-stamen, and even half-stamen and half-carpel; the same may be observed in double Pinks and Carnations. The ovules have been seen bearing pollen, while it is frequent to find the stamens bearing ovules. Illustrations obtained in this way might be multiplied *ad infinitum*. It should be observed, however, that in double flowers we frequently find not only all the essential organs replaced by petals, but an actual *multiplication* of the natural number of organs, as in Roses, Camellias, double Daffodils, &c.

Prolification.—In the last place, we may advert to the phenomena of the abnormal evolution of buds within the limits of flowers. Cultivated Roses sometimes send out a leafy shoot from the centre (prolification), the terminal bud not becoming arrested as is natural; on Apples and Pears we occasionally see one or two leaves growing out from the summit, from the same cause. In addition to this, the organs of the flower may assert their foliar nature by producing flower-buds in their *axils*, like stem-leaves. This has been observed in the case of the petals of *Celastrus scandens*, and also of *Clarkia elegans*, and occurs sometimes in garden Roses*.

These general observations will serve to show the essential *homology* of all the lateral organs of flowering plants with ordinary leaves, and more especially with the vaginal or leaf-scale portion of the leaves. The laws under which varieties of form &c. are produced within the limits of the flower all substantiate the same general principles.

Parts of the Flower.—The parts of flowers are:—the *perianth*, consisting of (1) the *sepals*, forming the *calyx*, (2) the *petals*, forming the *corolla*, and enclosing (3) the *stamens*, forming the *andrœcium*, and (4) the *carpels*, forming the *pistil* or *gynœcium*. That portion of the peduncle from which all these organs spring is called the *receptacle* or *thalamus*; it seldom has the internodes much developed, but is more or less expanded horizontally. It is sometimes convex or conical and elongated, and sometimes concave. When it forms a flattened

* A general review of these abnormal or unusual formations, and of the inferences that may be derived from them, is given in Dr. Masters' 'Vegetable Teratology,' published by the Ray Society.

surface above, its centre corresponds, of course, to the apex; and we may thus say that the above-named organs succeed each other from without inwards, or from below upwards.

The accompanying diagram of the floral whorls (fig. 157) illustrates the theoretical construction of a perfect and symmetrical flower. Here the internodes are imagined to be developed between the separate circles of the flower—an arrangement which does occasionally occur in nature, as in Capparids, Passion-flowers, &c.

Fig. 157.

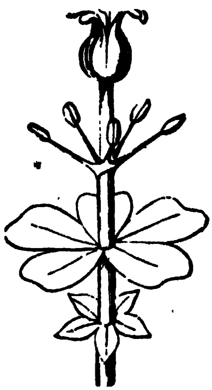


Diagram of the 4 circles of a typical 5-merous flower, separated by internodes.

Anterior and Posterior portions of the Flower.—All axillary flowers arise in the angle between a bract or leaf and the stem; from this is taken the rule as to the relative position of organs in describing flowers. The side of the flower next the stem is the *upper* or *posterior* part, that next the bract the *anterior* or *lower*; and in the diagrams or ground-plans used to represent the construction of flowers, it is important to mark the places of the axis and the bract, the former being represented behind by a ○, the latter in front by an *x* or ⌣, as in fig. 160.

Where flowers are solitary and *terminal* there is no proper back and front; but in plans of these, the position of the last leaf or bract, and specially of the bracteoles, should be shown. If, with a flower of four sepals, there is a pair of bracteoles, the two lowermost sepals are antero-posterior (fig. 167, p. 96); but if there are two pairs of bractlets, the two uppermost sepals are antero-posterior. When bracts are suppressed, as in the *Cruciferæ*, the position of the floral organs may be determined by their relation to the parent stem.

Arrangement of Parts.—The parts of flowers being phyllomes, their arrangement corresponds to that of stem-leaves. Sometimes they are truly whorled, while at other times, especially in the calyx and corolla, they are arranged in spiral cycles, and are *developed successively* on the $\frac{1}{3}$ or $\frac{2}{5}$ plan, but reduced into apparent whorls by the absence of internodes. Such flowers are called *acyclic*; and where some of the parts of the flower are arranged spirally and others in a verticillate manner, the term *hemicyclic* is given.

In such a calyx as that of the Rose, the sepals are imbricated on the $\frac{2}{5}$ plan (figs. 158–160). In the ternary floral envelopes of many Monocotyledons we find illustrations of the $\frac{1}{3}$ type. Sometimes the spiral

arrangement is still more evident, especially where there exist great numbers of a particular kind of organ, as in the mixed petals and stamens of *Nymphæa*, and the multiple pistils of *Ranunculus*, *Magnolia*, &c. In *Calycanthus* all the organs follow on in a continuous spiral.

In other cases the floral organs are *developed simultaneously*, when a true whorl is produced.

Fig. 158.

Fig. 159.

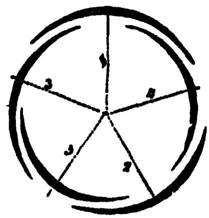


Fig. 158. Calyx of the Rose; the numbers indicate the sequence of the sepals from without inwards, or from below upwards.
Fig. 159. Section of the calyx of the Rose; the numbers as in the preceding figure.

Number of Parts.—According to the number of parts in a cycle or apparent whorl, these are distinguished as *dimerous* or *binary*,

Fig. 160.

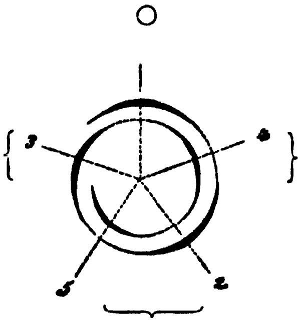


Fig. 161.

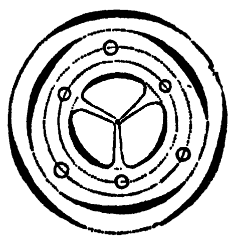


Fig. 160. Diagram of the $\frac{2}{5}$ spiral arrangement of the parts of the flower with bract and lateral bracteoles; O the situation of the axis.
Fig. 161. Diagram or ground-plan of the 3-merous flower of the Tulip.

trimerous or *ternary* (fig. 161), *tetramerous* or *quaternary*, and *pentamerous* or *quinary* (fig. 162). The ternary arrangement is by far the most common in the Monocotyledons, the quinary in the Dicotyledons.

Most frequently the calyx and corolla have an equal number of parts; the relative number of organs is prone to increase in the staminal circles, and still more frequently to diminish in the carpellary whorl.

Fig. 162.

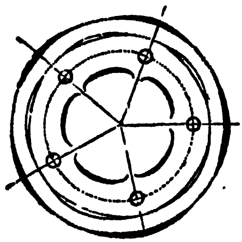


Diagram or ground-plan of the 5-merous flower of *Crassula*.

Alternation or Superposition.—In the majority of cases we find the organs of each successive whorl developed alternately with, and not super- or anteposed to, those of the preceding circle.

From this the whorls would appear to resemble the decussating whorls of true leaves, rather than regularly succeeding spiral cycles. We have seen that these decussating whorls are closely related to the spiral cycles (p. 48). Moreover we find in the very numerous cases of flowers with the organs imbricated in the bud, that the spiral arrangement is very evident, and the whorled appearance presents itself only after the expansion of the flower. Now, if the $\frac{1}{3}$ or $\frac{2}{5}$ cycles succeeded regularly, the organs of successive cycles should be superposed and not alternate, as indeed they sometimes are, e. g. *Sabia*. A. de Jussieu has supposed that the organs are arranged on the spiral $\frac{5}{13}$ type in all trimerous and pentamerous flowers with imbricated æstivation. Inspection of the diagrams in a former page (45) will show with how little displacement the organs of such flowers may be arranged on this type; and there is much probability that the alternation of spirally arranged cycles results from some such cause, while the alternation of organs in flowers with valvate æstivation is referable to the same laws as the decussation of whorls of leaves. The exceptional case of opposition of organs will be explained presently.

Typical Flower.—The typical flower in the diagrams (figs. 157, 162) consists of four circles of organs equal in size and number of parts, and with the parts regularly alternating. A flower thus presenting all the whorls is called *complete* or *eucyclic*; the organs in each circle being similar, it is *regular*; and the number of organs in each circle being the same, it is moreover *isomerous*.

Modifications.—Almost every kind of deviation and combination of deviations from this type are met with; but the modifications in the number, arrangement, and form of whorls or parts are referable to distinct causes, such as:—1. Alteration of the number of circles, or of the number of organs in the circles; this may arise either from *multiplication*, *chorisis*, *enation*, or *interposition*, or from *suppression* or *abortion* of parts. 2. Union of the organs; this

may be merely coalescence of the margins of organs of the same whorls (*cohesion*), or confluence of normally distinct whorls (*adhesion*). These so-called unions are generally the consequence of arrest of development, owing to which, parts usually separate in the adult condition remain *inseparate*. 3. Unequal growth or degree of adhesion in the organs of particular whorls, producing *irregularity*. 4. Irregular growth either of the receptacle, or production of outgrowths from various organs by *enation*. 5. Substitution of one organ by another (*metamorphosis*). 6. *Superposition*, where parts usually alternate are placed *opposite*, or, more correctly, are superposed the one to the other.

Dr. A. Gray has furnished an interesting illustration of these laws of modification, from a family (Crassulaceæ) in which different kinds of deviation occur together with examples of very symmetrical flowers. In *Crassula* (fig. 162) is found a symmetrical pentamerous flower, with five sepals, five petals, five stamens, and five pistils, all regularly alternating, and only slightly confluent at the base. In *Tillæa* some species have four, some only three organs in each whorl, but the flowers are still regular and symmetrical. In *Sedum* (Stonecrops, &c.) the flowers of some species are pentamerous, those of others tetramerous; but here the number of stamens is doubled by the introduction of an entirely new circle of these organs (*multiplication*). *Rochea* has the margins of its petals slightly *coherent*, while in *Grammanthes* the petals and sepals are respectively *coherent* more than halfway up. *Cotyledon* has *coherent* envelopes, and a double series (*multiplication*) of stamens as in *Sedum*, to which is added an *adherence* of the stamens to the tube of the corolla. In *Penthorum* the five styles are *coherent* firmly together below, while in some cases its petals are *suppressed*. In *Sempervivum* (Houseleek) the number of sepals, petals, and pistils varies in different species from six to twenty, and the stamens from twelve to forty.

Pleiotaxy, or multiplication of the number of whorls, is very common, especially as regards the stamens. In the trimerous flowers of Liliaceæ and Amaryllidaceæ there are six stamens standing in two circles of three. In the Poppy family the tetramerous circles are still more multiplied; and in the Rose, Buttercup, &c. we have further examples. When the number exceeds three or four circles of one kind of organ, the organs are said to be *indefinite* in number, and the verticillate arrangement becomes very indistinct in the opened flower. In the White Water-lily (*Nymphæa*) we have multiplication both of petaline and staminal circles; and in *Magnolia*, *Ranunculus*, &c. the pistils are much multiplied, exhibiting in these a distinctly spiral arrangement.

Multiplication of circles occurs abnormally in the *double flowers* of gardens, in which we often find far more organs than exist in the normal state, as in Daffodils and other flowers where the organs are naturally few

in number. The multiplication in this case is often due to *transverse chorisis*, the parts being superposed to each other. Each part so affected divides in a direction parallel to its surfaces into two or more parts. If the supernumerary part is an outgrowth from an already formed organ it is said to be formed by *enation*.

Pleiomery, or multiplication of the organs in particular whorls, occurs in a number of flowers, and depends on different causes. Sometimes the multiplication is effected by *collateral chorisis*, or division at right angles to the surfaces, a pair of stamens, for example, standing in place of one; in other cases the organ is divided parallel with the surfaces into an inner and outer part or into a fasciculus of organs. The cases of *collateral chorisis* are explained by the circumstance that the staminal leaf, in these cases, as in an ordinary lobed or compound stem-leaf, becomes subdivided and forms a *lobed* or *compound stamen*. In some flowers (as in many Ericaceæ) there are ten stamens in one whorl, while the sepals, petals, and carpels are pentamerous; in these cases the five additional stamens are formed subsequently to the others. This mode of multiplication of parts is called *interposition*.

Suppression, Abortion.—In describing the phenomena of diminution of the number of circles or organs of flowers, it is convenient to distinguish between *suppression* or total absence, and *abortion* or partial absence, when the organs are represented by imperfect or rudimentary structures.

A *complete* flower possesses a calyx and a corolla; the corolla, and even the calyx also, are wanting in some flowers, which are termed *incomplete*; when the corolla alone is wanting, the flower is *apetalous*; the term *naked* is occasionally applied to flowers without any floral envelopes.

The term *dichlamydeous*, having calyx and corolla, *monochlamydeous*, having calyx alone, and *achlamydeous*, destitute of floral envelopes, are used by some systematic botanists in place of the above. These conditions are not very secure bases for systematic divisions, since it is not uncommon to find apetalous plants in Orders having ordinarily complete flowers, as in the Caryophyllaceæ (*Sagina*, &c.): the apetalous condition, however, is constant in a large number of Orders, and familiar examples occur in the Nettle family, the Chenopodiaceæ, the Amaranths, &c. Achlamydeous flowers occur in the Willows, *Callitriche*, &c. Some flowers, then, are incomplete by abortion, in which case they are degenerate conditions of a more perfect type, or they are incomplete by suppression, when they are typically of a relative low degree of organization.

When *essential organs* (stamens and pistils) of both kinds are present, the flower is called *hermaphrodite* or *bisexual* (this condition is indicated by the sign ☿). It must be remembered, how-

ever, that the term hermaphrodite is used in its morphological, not in its physiological significance, for many flowers hermaphrodite in structure are practically unisexual in function. In many plants one of the circles of essential organs is suppressed, so that a given flower has only stamens or only pistils; such flowers are termed *unisexual* or *diclinous*. The unisexual flowers are called respectively *staminiferous* or *male* (♂), and *pistilliferous* or *female* (♀). When flowers of both kinds occur on the same plant, this is called *monœcious* (Oak, Birch, Vegetable Marrow, &c.); when they are on distinct individuals, the plant is termed *diœcious* (Hop, Willow, Bryony, &c.); when, as in some cases, the imperfection results from a kind of regular abortion rather than total suppression, and the same plant or species exhibits at once staminate, pistillate, and hermaphrodite flowers, it is termed *polygamous* (*Parietaria*, many Palms, Maples, &c.). Some plants bear *neuter* flowers, destitute of both stamens and pistils: such is the case naturally with the outer florets of many Composites, and it is constantly seen in the garden Snowball (*Viburnum Opulus*) and *Hydrangea*.

The *diclinous* or *unisexual* condition is often typical and hereditary in certain families, such as Amentiferæ, &c.; but cases of diclinism occur not unfrequently in exceptional genera of families the majority of whose genera are bisexual, as in *Ruscus* among the Liliaceæ; or in exceptional species (by abortion), as in *Lychnis dioica*; sometimes it occurs by abortion in species normally possessed of perfect flowers, as in *Asparagus*.

Arrangement of Parts.—The suppression of an entire circle renders a flower unsymmetrical; for when the corolla is absent, we find the stamens commonly *superposed* to the segments of the preceding circle, as in *Chenopodium*; but this is in accordance with the normal type, as the stamens should be superposed to the sepals, the intermediate petals (here suppressed) alternating with both. Not unfrequently we find abortive organs, such as sterile filaments or "glands," of various kinds forming circles which restore the symmetry of apparently unsymmetrical flowers.

The cases of unsymmetrical conditions arising from the superposition of the organs of succeeding whorls are explained by some entirely by *suppression* or *abortion*; others more correctly refer some of these cases to *chorisis*. In *Geranium* we find alternating with the petals five little glands which must be regarded as abortive stamens, since in the succeeding whorl the five stamens alternate with these and stand in front of the petals; the five innermost and longer stamens, again, are superposed to the glands. In *Erodium* the outermost row is represented by glands, the second row by sterile filaments, and only five perfect stamens exist. Much the same conditions occur in the Linaceæ. On the ground of such facts as these,

the superposition of the stamens to the petals in Rhamnaceæ, the Vine, &c. has been explained by supposing a circle of stamens to have been suppressed between the petals and the existing stamens. Several recent writers attribute the stamens of Rhamnaceæ to chorisis of the petals with suppression of the true stamens, extending the same explanation to Byttneriaceæ and the Vine, where the true stamens are represented by sterile rudiments or glands *within* the existing stamens. In the Primrose, according to Pfeffer, the petals originate from the backs of the stamens, though in other cases it would seem that the stamen arises from the petal. In Primulaceæ the opposition of the stamens to the petals may, however, be a result of suppression; for in *Samolus* we find five lobes on the throat of the corolla alternating with the petals, while *Lysimachia ciliata* has five sterile filaments in addition to five perfect stamens.

Isomery, Anisomery.—Suppression or abortion of part of the organs of one or more circles is, as has been said, a very common cause of want of symmetry. This occurs by far most frequently in the carpellary circles, as might he expected from the organs being crowded on the point of the receptacle (multiplication of carpels occurring, on the other hand, where the receptacle is unusually developed); the stamens exhibit it not unfrequently; and it is observed also in the petaline whorl, and even in the calyx.

Symmetrical flowers may be either dimerous, trimerous, tetramerous, or pentamerous throughout; and when the organs are equal in all the circles the flowers are *isomerous*, if not so they are *anisomerous*: thus we have isomerous dimerous flowers in *Circæa* (fig. 163) and *Syringa* (fig. 164), isomerous pentamerous flowers in *Crassula* (fig. 162), before

Fig. 163.

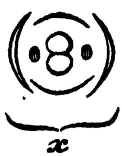


Fig. 164.

Fig. 165.

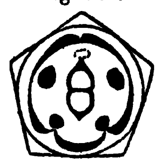


Fig. 163. Ground-plan of the 2-merous flower of *Circæa*: *x* represents the bract.
Fig. 164. Ground-plan of the Lilac, with 2-merous circles: *x*, the bract; *a*, *a*, bracteoles.
Fig. 165. Ground-plan of a labiate flower, with didynamous stamens; the posterior one (dotted) suppressed.

referred to; but, generally speaking, one or other of the whorls exhibits partial suppression.

It is rare to find the sepals *partially* suppressed: perhaps we may consider this to be the case as regards the limb of the sepals in such instances as the pappus of *Bidens*. The corolla exhibits partial suppression in some Leguminosæ, where, although the plan of the flowers of the order is pentamerous, in *Amorpha* only one petal exists; a transition towards

this occurs in other genera of the order, where, indeed, the four petals here suppressed are generally considerably smaller. In the Larkspurs (*Delphinium*) one petal is constantly suppressed, while the others are of irregular form; and in Aconite three out of the five petals are inconstant in their occurrence, being, even when present, mere petaloid scales.

The stamens are mostly *isomerous*, with either one, two, or more whorls, when the floral envelopes are regular, although there are well-known exceptions to this. The suppression or partial abortion of some of the stamens is most common where the flowers are irregular. This suppression is well seen in the irregular monopetalous Orders, where we find curiously graduated illustrations of the phenomenon. Thus, in the Scrophulariaceæ, belonging to the pentamerous type, there are usually but four stamens, but *Verbascum* has the fifth (not always fertile); *Pentstemon* has four perfect stamens and a sterile filament; and in *Scrophularia* the fifth is represented by a scale in the upperside of the corolla. In *Veronica* three are suppressed, and only two remain. In the Labiatæ (fig. 166), again, one stamen is ordinarily suppressed; not unfrequently two of these appear as sterile filaments; and in *Salvia, Monarda*, and other genera only two stamens exist.

Either *multiplication* or *suppression* is almost the rule in the carpellary circle, the isomerous condition being rather the exception. Six carpels, or a double circle, occur in the 3-merous flowers of *Triglochin* (fig. 166); and we have mentioned the occurrence of five carpels in the pentamerous flowers of *Crassula* and *Sedum*; in the nearly allied Saxifragaceæ the carpels are usually reduced to two. In Araliaceæ, *Aralia* has five carpels, different species of *Panax* three and two, while in the allied order

Fig. 166.

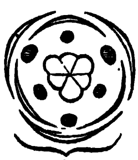


Fig. 167.

Fig. 166. 3-merous flower of *Triglochin maritimum*, with six carpels; *x* represents the bract.
Fig. 167. Ground-plan of *Epimedium*, with 2-merous circles and a solitary carpel; *a, a* are the bracteoles of the pedicel.

Umbelliferæ the number 2 is universal in the carpellary circle, although all the other circles remain pentamerous. In Rosaceæ we have almost every conceivable condition; for while multiplication takes place to a great extent in *Rosa, Fragaria*, and allied genera, the normal five carpels occur in *Spiræa* and the Pomaceous suborder; in *Agrimonia* the number is reduced to two; *Sanguisorba* has two or one; while in the Drupaceous suborder, in *Prunus* &c., only one carpel regularly exists, a condition which is the rule throughout the related extensive pentamerous order Leguminosæ. In Ranunculaceæ the number of carpels varies much. In Berberideæ the outer circles are 2-merous and the carpel is solitary (fig. 167). Suppression of a portion of the carpels is almost constantly

found in the monopetalous Orders, where we seldom have more than two.

Suppression of organs becomes exceedingly striking when associated with suppression of entire whorls. Thus in *Callitriche* the floral envelopes are wanting, and while the pistil indicates the tetramerous type, three stamens are suppressed, so that the perfect flowers consist of one stamen and one pistil, and the imperfect flowers often met with are composed respectively of a stamen and a pistil. The latter condition occurs also in the greatly reduced flowers of our native species of *Euphorbia*, in which the involucre encloses one naked female flower, consisting simply of a pistil, and a number of naked male flowers reduced to the condition of a single stamen (see Euphorbiaceæ).

A curious kind of regular suppression, not interfering with symmetry, is sometimes met with, where the typical pentamerous condition is replaced by the tetramerous, either in flowers of the same plant or on different individuals of the same species. Thus, in *Ruta*, in some species of *Sedum*, and some *Alsineæ*, the flowers have the organs sometimes in circles of fives and sometimes in circles of fours, without any other accompanying deviations from the character of the species.

Congenital Union or Inseparation.—Union of the organs of the flower consists either in *cohesion* of the parts of a whorl with their fellows, or in *adhesion* of organs of one whorl to those of another. Both occur in almost every possible degree. It must be borne in mind, however, that these terms are often applied to cases wherein there has really been no union of previously disunited organs, but a want of separation between parts originally uniform, but which in other cases become in process of growth disjoined.

Cohesion occurs in the calyx, producing what is called a *gamosepalous* or *synsepalous* calyx; also in the corolla rather less frequently, forming a *gamopetalous* or *sympetalous* corolla. With these terms are contrasted *polysepalous* and *polypetalous* (or *dialy-sep-petalous*), used to indicate that the sepals and petals are *distinct*, *i.e.* not coherent.

In the Vine the petals cohere above, while they are distinct below, and the flower opens by the separation of the corolla from the receptacle; the sepals of *Eschscholtzia* are entirely coherent, and fall off like a cap.

Union is less common among the stamens; but in some Orders they are coherent by their filaments into one piece (*monadelphous*), in others into two or more parcels (*diadelphous*). Such cases are usually due to a branching or lobing of the primary staminal leaves, and not to any real union of previously disconnected parts. Other plants have the anthers coherent (*syngenesious*), while the filaments are free; and in some diclinous flowers the stamens are united into a kind of column.

The carpels exhibit every degree of confluence, from a slight coherence at the base to a firm union by their sides, complete confluence of the ovary with the styles free, confluence of ovaries and styles in part or entirely with free stigmas, and complete confluence of ovaries, styles, and stigmas. In Asclepiadaceæ we have confluence of the styles, while the ovarian portions of the carpels are only slightly coherent.

The details regarding coherence will be treated of more conveniently in the chapters on the separate organs.

Adhesion may exist between the inner and outer circles of the floral envelopes, between petals and stamens, and between stamens and pistils, also between calyx, corolla and stamens with pistil free; or the calyx, corolla, and stamens may all adhere to the pistil. No case is known of adhesion of the three inner circles with a free calyx.

What is commonly termed *adhesion* is, as before explained, more strictly want of separation between parts which ordinarily become detached one from the other during growth.

Insertion.—The point of emergence of an organ is inappropriately called its *insertion*; and when an organ is not adherent to any other circle, but emerges directly from the receptacle, it is said to be *free*.

When the outer organs spring from the receptacle, they are called *hypogynous* (fig. 168), signifying below the pistil; if the stamens appear to adhere to the free tube of the calyx or corolla, they are said to be

Fig. 168.

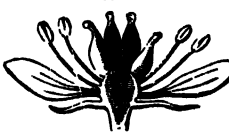


Fig. 169.

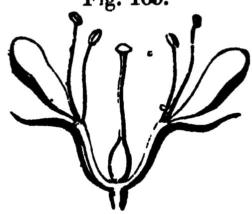


Fig. 168. Hypogynous flower of *Ranunculus*, in section.
Fig. 169. Perigynous flower of *Prunus*, in section.

perigynous (fig. 169); while if the tube of the calyx or receptacle is carried up and adherent to the sides of the pistil, the stamens become apparently *inserted* on the top of the ovary, and are then called *epigynous* (fig. 170).

Some other terms are used in reference to the insertion of the petals and stamens: thus, *thalamifloral*, or emerging from the receptacle, is synonymous with hypogynous (fig. 168); *calycifloral*, indicating emergence from the throat of the calyx, may agree with either the perigynous (fig. 169) or epigynous (fig. 170) conditions; while *corollifloral*, emergence from the tube of the corolla, is a form of the perigynous insertion.

The terms *inferior* and *superior* are occasionally applied to the calyx, according as it is *free* (fig. 168) or *adherent* (fig. 170) to the pistil all the way up; occasionally it is half-superior (*Saxifraga*, fig. 171). The same terms are also applied to the pistil in the reversed sense to indicate the

same conditions: *i. e.* when the calyx is inferior, the free ovary is superior, and *vice versâ*.

The terms *perigynous*, &c., and *calycifloral*, &c. are in constant use and very convenient, but they may convey false notions as to actual structure. In the perigynous flowers of Rosaceæ, for example, such as those of *Fragaria*, *Geum*, &c., the stamens really rise from an expansion of the receptacle, forming the so-called throat of the calyx, and in *Rosa*, *Pyrus* (fig. 172), and other similar forms the carpels are really enclosed in an excavated receptacle or *receptacular tube*, from the upper edge of which sepals, petals, and stamens arise. In these cases the receptacle instead of lengthening into a conical extremity becomes tubular.

Fig. 170.

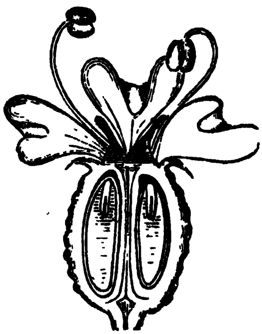


Fig. 171.

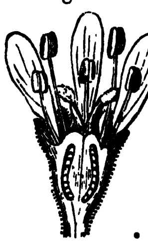


Fig. 172.

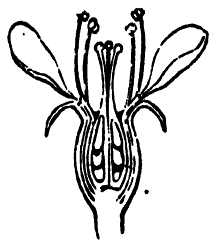


Fig. 170. Epigynous flower of an Umbellifer in section; pistil completely inferior.
Fig. 171. Flower of Saxifrage in section, with a partially adherent calyx and half-superior pistil.
Fig. 172. Flower of *Pyrus* in section; pistil inferior, calyx superior, corolla superior, stamens perigynous.

The adherence of stamens to pistils produces what is called the *gynandrous* condition, so remarkable a character of the Orchidaceæ and Asclepiadaceæ.

Irregular growth.—Irregularity of flowers arising from unequal *size*, different *form*, or unequal degree of *separation* of the organs or whorls is extremely common. Different form and size produce irregularity in the floral envelopes and stamens of many plants where these are free; and this is often associated with irregularity arising from suppression. The irregular union occurs alone, or is superadded to all the rest when the organs are coherent; this condition is oftenest found in the floral envelopes, in the stamens less frequently, and in the pistils perhaps not at all.

Irregular polypetalous flowers illustrating this point present themselves in Papilionaceous plants, in Fumariaceæ, Violaceæ, &c.; irregular polysepalous calyces occur in *Aconitum*, *Delphinium*, &c. Stamens are gene-

rally alike in the same circle; but in *didynamous* stamens (two long and two short) there is an exception to this. Irregular gamosepalous calyces and irregular gamopetalous corollas are met with in endless variety of forms, in the majority of which there is a tendency of the component organs of a whorl to associate together in two groups, front and back, so as to produce a bilabiate condition, as in the corollas of most Labiatæ and Scrophulariaceæ. Unequal degree of union of stamens produces the *diadelphous* condition of many Leguminosæ, and the still more irregular *polyadelphous* condition in the Orange. These points will be further explained in the next Sections.

It may be repeated here, that the deviations from irregularity falling under this head almost universally arise during the development of the bud from its originally regular rudiments.

Development of the Thalamus.—Most flowers have only very short or contracted internodes developed between the whorls; that is to say, the receptacle or thalamus is usually not lengthened. Exceptions occur to this, however; for in the Caper tribe we have long internodes between calyx, corolla, stamen, and pistil.

Fig. 173.

Fig. 174.

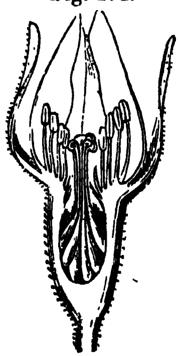


Fig. 175.

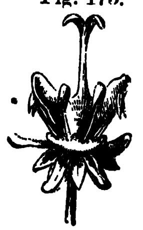


Fig. 173. Section of a flower of *Silene*, with an internode between the calyx (which is turned back) and the corolla.
Fig. 174. Section of the flower of the Rose; the pistils seated in a hollow receptacle.
Fig. 175. Flower of the Maple (*Acer*), with the petals removed, showing the stamens arising from an hypogynous "disk" or outgrowth from the receptacle.

In *Dianthus* and *Silene* (fig. 173) there is a short internode between the calyx and corolla, in *Gentiana* between the stamens and the pistil. In the Rose (fig. 174) the receptacle is expanded into a cup, from the inner walls of which the carpels arise; and in *Nelumbium* the carpels are immersed in a large fleshy receptacle. In many cases what is termed *calyx-tube* is in reality a tubular prolongation of the receptacle, from the edge of which the calyx, petals, and stamens arise. In the Pæony the receptacle is raised up into a kind of cup or "*disk*" round the carpels, in

P. Moutan enclosing them all but the stigmas: the apparently inferior position of the ovary of *Victoria* depends on the discoid development of the receptacle where the outer floral circles are inserted. A ring of similar nature, free from the ovary, occurs in *Alchemilla*. Another condition exists in the Mignonette (*Reseda*), where the cup-like or annular development of the receptacle is inside the floral envelopes, and forms a support to the stamens surrounding the ovary. This form of the "disk," which occurs also in *Acer* (fig. 175), must not be confounded with those depending on the presence of perfect or imperfect whorls of abortive floral organs. The epigynous disk of Umbelliferæ (fig. 170) and allied orders is probably a development of the receptacle, since the so-called adherent tube of the calyx is perhaps an excavated receptacle. In *Circæa*, and to a greater or less extent in other Onagraceæ, the epigynous process supporting the floral envelopes and stamens is prolonged into a tube above the inferior ovary, surrounding the long free style. Where organs are multiplied, we often find the thalamus lengthened into a conical or clavate body, to give room for the insertion, as with the pistils of *Ranunculus* (fig. 168), *Magnolia*, *Fragaria*, &c. In Geraniaceæ the receptacle is prolonged into a column in the centre of the confluent styles; and the same occurs to less extent in *Euphorbia*.

When a circle of organs is removed from its predecessor by a stalk-like internode, it is called *stipitate*. The column supporting the carpels of *Geranium* (p. 143, fig. 276), or those of Umbelliferæ, is termed a *carpophore*; the stalk of the ovary of *Gentiana* is a *gynophore*; a stalk above the corolla, supporting both stamens and pistils, as in Passion-flowers, is a *gynandrophore*. The form of the flower is dependent in many cases on the *obliquity* of the receptacle, as in Leguminosæ, *Aconitum*, *Delphinium*, and many other irregular flowers.

Enation, Substitution, Superposition.—The modifications arising from *enation* have been already alluded to; while those dependent on the *substitution* of one organ for another, as in many double flowers where the stamens are replaced by petals, demand only passing notice. *Superposition* arises from various causes, as from the abortion or suppression of a part that should come between and alternate with the superposed parts, or it may arise from *chorisis* or *enation*, or from true superposition of successive cycles, as in *Sabia*, and possibly by growth in the axil in the same way that a bud is axillary to a leaf.

Causes producing modifications.—The modifications met with in the construction of flowers may be dependent upon arrest, exaltation, or perversion of growth or of development, either separately or in conjunction. By growth is meant mere increase in bulk, by development the progressive change in the form and structure of organs (metamorphosis) which takes place in the course of their passage from the initial to the adult stage. By the action of the causes above mentioned, the parts of a plant vary in composition (simple or divided leaves, &c.), number (increased or diminished),

arrangement (spiral, opposite, or verticillate, &c.), freedom or union, form (regular or irregular), order of growth (consecutive, simultaneous, intercalary, definite, indefinite or interrupted, congenital or postcongenital, &c.).

These changes may be *congenital* and *hereditary*, and then common to all plants that have originated from a common ancestral type; or *acquired* or *adaptive*, when they have become manifest in order to fulfil certain special or individual requirements, or to put the plant in harmony with the circumstances under which it has to live. Thus the form, colour, and perfume of flowers are often in direct relation to the habits and structure of the insects which visit them for the sake of the honey, and whilst so engaged effect the fertilization of the flower in ways hereafter to be mentioned. It may thus be said that the form of the plant and its parts is dependent, 1st, on hereditary endowment, and 2nd, on adaptation to the work it has to do, the means it has of doing it, and the circumstances under which it must be accomplished. Sometimes from causes only imperfectly understood there is a *reversion* from a more complex or adult to a simpler or embryonic form, as when a petal or a stamen becomes leafy; and other cases of similar character may sometimes be explained hypothetically by assuming them to be reversions to an ancestral form.

Diagrams, Floral formulæ.—For purposes of ready comparison, and to avoid lengthy descriptions, diagrams or plans and floral formulæ are made use of.

A *diagram* is intended to show the number, arrangement, and relative position of the parts of the flower. Thus, fig. 162, p. 91, represents the diagram of a complete, regular, isomerous, pentamerous flower. Fig. 161, p. 90, shows a trimerous flower, with the parts in regular alternation. Diagrams of this kind are spoken of as empiric when they represent the actually existing state of the flower, while they are termed theoretical when the condition shown is that assumed or known to be the typical one, apart from the modifications brought about by abortion, chorisis, &c. Thus, fig. 165, p. 95, shows the usual condition in Labiates, where there are four stamens, the situation of the fifth, which is abortive, being shown by the dotted circle.

In place of diagrams *floral formulæ* are sometimes made use of. These are constructed in various ways according to the views of various authors, though it would be convenient if uniformity of practice could prevail in this matter. The following illustrations will exemplify these formulæ; thus a regular pentamerous eucyclic flower may be represented thus:—

$$S\,5 \quad P\,5 \quad A\,5 \quad G\,5;$$

the S representing the calyx of five sepals, P the corolla of five petals, A the andrœcium of five stamens, and G the gynæcium or pistil of five carpels, each whorl distinct from each other, and the parts of each individual whorl also distinct and free from cohesions or adhesions so-called. In the instance given, the parts are assumed to be all in their proper alternate position; but this might be more clearly shown thus:—

$$\begin{array}{cccc} S\,5 & & A\,5 & \\ & P\,5 & & G\,5 \end{array}$$

or more briefly thus:—

$$F\,5 = {}^{S}\,{}_{P}\,{}^{A}\,{}_{G}$$

the F standing for flower.

In order to indicate cohesion a line or a bracket over the letters may be used, and a similar line placed vertically by the side of the letter may represent adhesion; thus the formula

$$F\,5 = {}^{\overset{\frown}{S}}\;{}_{|\overset{\frown}{P}A}\;{}^{\overset{\frown}{G}}$$

may be taken to represent the flower of a Primrose, in which the five sepals are coherent, the five petals likewise coherent, the five stamens free among themselves, but superposed and adherent to the corolla, and lastly the five carpels coherent one with the other. The spiral or verticillate arrangements may also be indicated by similar devices, thus:—

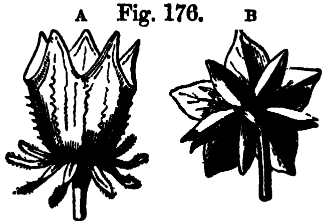
$$\sim S\,\tfrac{2}{5}\;P\,5\;\sim A\,\infty\,\overset{\frown}{G\,5}$$

would indicate a calyx of five sepals arranged spirally on the $\frac{2}{5}$ plan, a corolla of five petals verticillate, an andrœcium of numerous stamens arranged spirally, and a gynæcium or pistil of five coherent carpels, the sign $\sim$ indicating a spiral arrangement, and the sign ∞ always indicating an indefinite number of parts or too many to be readily counted *.

Sect. 8. The Floral Envelopes or Perianth.

Calyx and Corolla.—The floral envelopes of a typical flower consist of two circles of organs, forming the *calyx* and *corolla*. There is no fundamental difference between sepals and petals (the organs which compose these circles); and the only general definition that can be given is, that the outer circle (or, if only one circle exists, that circle) is the calyx; the corolla consists of the second circle (or sometimes of additional circles) of foliar organs intervening between the calyx and the stamens. In some few cases the perianth or floral envelopes are entirely wanting, as in many Aroids.

A Fig. 176. B



Calyx with epicalyx.
A. *Hibiscus* (Malvaceæ).
B. *Potentilla* (Rosaceæ).

The above definition of the calyx is liable to exception in rare cases; for in the Malvaceæ, the Dipsaceæ, and some Rosaceæ the true calyx

* For details relating to the morphology of the flower the student should consult Eichler's 'Blüthendiagramme,' Sachs's Text-Book, and Masters's 'Vegetable Teratology.' Reference should also be made to the account of the principal natural orders in the following pages, wherein the general principles of morphology are illustrated by reference to their particular application to different orders.

is double, that is, a circle of smaller organs, resembling sepals, or a tubular cup, stands outside the proper calyx, forming what is called an *epicalyx* (fig. 176). The ambiguity in these cases is removed by the existence of a well-developed coloured corolla inside the calyx.

The *epicalyx* of Malvaceæ, like that of Dipsaceæ, is perhaps to be regarded as an involucre of bracts. That of *Potentilla* (fig. 176, B) and allied genera is sometimes supposed to represent confluent lateral lobes or stipular appendages of the sepals.

Perianth.—The terms *perianth* or *perigone* are used in a *general* sense to signify all the floral envelopes, and are *specially* applied to instances where the distinctions between calyx and corolla are not apparent, *e.g.* when the sepals and petals are all petaloid, as in the Tulip, &c., and when they are all green and sepaloid, as in the Dock, &c. The words are also applied to the calyx in the Orders where it regularly exists alone, either in a sepaloid or petaloid condition, as in *Daphne* and the Monochlamydeous orders generally.

Æstivation.—The arrangement of the floral envelopes in the bud, the *æstivation* or *præfloration*, is a subject of great importance in systematic botany, as affording very regular characters in the majority of the natural orders.

The plans of æstivation given in illustrative works (fig. 177) are taken from horizontal sections of the bud just before it opens; and in cases where the sepals or petals are coherent below, the section is supposed to pass through the free lobes of the limb.

The æstivation of flower-buds agrees essentially with the vernation of leaf-buds (p. 72), especially as regards the folding of the individual organs; the sepals and petals may be *reclinate, conduplicate, plicate, convolute, involute* (a still further rolling-in rendering this *induplicate*), *revolute* (in excess becoming *reduplicate*); *circinate* as in the petals of *Hamamelis*, and an additional case is found in Poppies and some other flowers, where the petals are irregularly crumpled-up, or *corrugate.*

[Collectively the arrangement of the organs is either *imbricate, valvate,* or *open.* *Imbricate.*—The varieties of this kind are best seen in whorls of five, which furnish four distinct forms of æstivation, each being deducible from that which precedes it, by shifting the edge of one petal, as follows:—1. *Quincuncial,* or the $\frac{2}{5}$ plan (fig. 177, A). 2. *Half-imbricate* (B), which only differs from the last in that the 4th part overlaps the 2nd. 3. *Imbricate proper* (C), in which the 5th part overlaps the 3rd. 4. *Convolute* (D), in which the 3rd part overlaps the first. If convolute petals are twisted, they are called *contorted* (fig. 177, F). In other words, the axis of a median line down each petal is erect in the simply convolute, but spiral in the contorted.

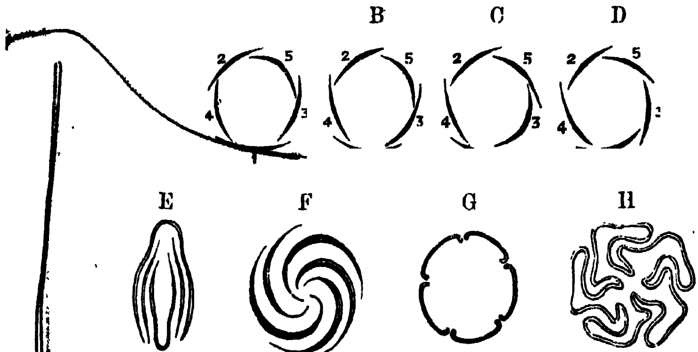
Imbricated whorls with four or three parts are usually either imbricate proper or convolute. Whorls with two parts are often *equitant* (fig. 125), as are the petals of Poppies; or *half-equitant*, as the sepals of Poppies, of which each part has one edge overlapping an edge of the other. These two conditions may be regarded as degraded forms of the imbricate proper and convolute respectively.

A special form of the half-imbricate is seen in the æstivation of papilionaceous corollas (fig. 177, E), and is named *vexillary*, from the posterior petal, which is called the *vexillum*, or "standard." The order of the petals is as follows:—The standard is No. 1; either keel-petal is No. 2; the wing-petal on the opposite side of the flower to the last is No. 3; the other wing No. 4; and the remaining keel-petal is No. 5. Thus No. 4 will be seen to overlap No. 2 (see figs. 191–193, p. 111).

The æstivation of the Snap-dragon (*Antirrhinum majus*) is called *cochlear*, but it is really half-imbricate.

When the organs are coherent at their margins they may become variously *plaited* or *plicate*, the portions sometimes assuming the contorted character, as in the corolla of the *Convolvulus* (fig. 177, H).

Fig. 177.



Æstivation of corollas.

A. Quincuncial. B. Half-imbricate. C. Imbricate. D. Convolute. (After G. Henslow.) E. Vexillary æstivation of the corolla of a Papilionaceous flower. F. Contorted æstivation of the corolla of *Malva*. G. Valvate æstivation of the corolla of *Vitis*. H. Plicate æstivation of the corolla of *Convolvulus*.

Valvate æstivation.—This kind of æstivation occurs when the margins meet but do not overlap (fig. 177, G). If the margins of the organs are rolled inwards they are *involute* or *induplicate* (fig. 127); if, on the other hand, they are rolled outwards, they are called *revolute* or *reduplicate*, in both of which cases the rolled borders only are in contact, and not the absolute margins.

Open.—This is also called "straight." The parts of the whorl, usually the calyx, are so rudimentary or arrested in growth, that they do not even meet, as in the *Umbelliferæ*, *Rubiaceæ*, &c. Hence this æstivation may be said to be *indeterminate.*—G. H.]

The calyx and corolla may both have the same æstivation, or they may be different; and their characters may hold good for all the species of a genus, as in *Hypericum*, in which the calyx is quincuncial and the corolla contorted, or even for all the genera of an order, as of Malvaceæ, in which the calyx is valvate and the corolla convolute or contorted; but it is very common for a species to have several varieties in different individual flowers, even on the same plant.

The direction of the spiral in imbricated æstivations is variable, often in the same plant: occasionally the direction changes in passing from the calyx to the corolla; at other times it remains the same; and this character is sometimes constant, in other cases very inconstant. In determining the direction of spirals, right-hand or left-hand, it is usual to suppose one's self standing in the axis of the organ; but many authors suppose themselves standing in front of it—for instance, in the place of the bract of a flower, which gives the exact opposite of the former; hence great confusion in the application of the terms *dextrorse* and *sinistrorse*.

Calyx.—The calyx is the outermost circle of the floral envelopes. It is composed of phyllomes or modifications of leaves, called *sepals*; according as the sepals are distinct or coherent, the calyx is termed *polysepalous* (or *dialysepalous*), or *monosepalous* (or *gamosepalous*).

The exceptions to the absolutely external position of the calyx have been pointed out.

The Sepals generally bear more or less resemblance to bracts, being attached by a broad base, seldom articulated, without any stalk, and of a green foliaceous texture; not unfrequently, however, their texture is of the coloured and delicate nature described as petaloid. They are usually *entire*, but the margins are sometimes cut, as in the Rose (fig. 158), and they are occasionally reduced to scale-like, or even feathery or hair-like processes. They are likewise subject to the production of pouches, spurs, &c., especially at the lower part, both when distinct and when coherent; and the apex is often more or less prolonged into a point or spine. Their mode of venation is usually like that of the sheath of the leaf.

Some confusion is liable to arise in the condition called a *superior* calyx, where the segments are totally free: if we suppose an adherent tube to exist below, such a calyx would be monosepalous; but the so-called calyx-tube is usually a cup-like receptacle, and the sepals originate or

become detached from the point where they appear to be inserted—for example, in Rosaceæ, Umbelliferæ, Cucurbitaceæ, Compositæ, &c.

Polysepalous Calyx.—In the polysepalous calyx, if the sepals are alike and symmetrically arranged, the calyx is *regular*; if some of the sepals are larger than others (*Helianthemum*, *Cheiranthus*, fig. 178) it becomes *irregular*; and this is still more the case when the sepals differ in form as well as size. Some of the most remarkable irregular forms of polysepalous calyx occur accompanied by a petaloid condition, as in *Aconitum* (fig. 179) and *Delphinium*.

The coloured calyces, both regular (*Fuchsia*) and irregular, may be easily mistaken for corollas; but they are known by their exterior position, and in some cases by the existence of a more or less perfect corolline circle within.

Direction.—The direction of sepals (whether distinct or partially coherent) is indicated by technical terms; thus they may be *erect*, *connivent* (the points turning in), *divergent*, or even *reflexed*.

Fig. 178.

Fig. 179.

Fig. 180.

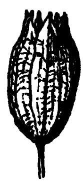


Fig. 178. Irregular polysepalous calyx of *Cheiranthus*. Two of the four sepals are dilated or "gibbous" at the base.
Fig. 179. Irregular polysepalous coloured calyx of *Aconitum Napellus*.
Fig. 180. Regular gamosepalous calyx of *Silene inflata*.

Parts of a Gamosepalous Calyx.—When the sepals are confluent or not separated, the *gamosepalous* calyx (fig. 180) is usually described as a whole. The part where the sepals are coherent or are still inseparate is the *tube*; the upper boundary of this is the *throat* (*faux*); and the free or spreading portion constitutes the *limb*—composed of *lobes* or *teeth* with intervening *sinuses* when the upper part of the sepals is more or less distinct; *entire* when the sepals are so completely confluent that the compound nature is not indicated by any teeth or fissures at the free edge.

It is necessary not to confound the *receptacular tube* with the *calyx-tube*

proper. An investigation of the course of development will show the difference between the two, and, generally speaking, the position of the petals and stamens; if the latter are *perigynous*, it is probable that the tube below is receptacular. The venation and internal structure will also serve as guides in this matter, inasmuch as the receptacular tube contains not only its own vascular bundles, but those of two or more verticils of flowers, and which are derived from the primary ones by subdivision.

Form.—The gamosepalous calyx is subject to the same kinds of modification as that in which the sepals are distinct. It is either *regular* or *irregular*.

Of the *regular* kinds we find a large number which present forms admitting of general technical names, such as *tubular* or *cylindrical*, *cup-shaped*, *infundibuliform* or funnel-shaped, *campanulate* or bell-shaped, *urceolate* when the tubular form is expanded below, *turbinate* or *top-shaped* when expanded above, *inflated* when the lateral view is oval or roundish with a narrow mouth (fig. 180), &c. In some species of *Campanula* there are regular appendages at the bottom of the sinuses between the teeth. In *Primula* and some other genera the tubular calyx is angular or plaited.

Calyces nearly resembling the above are rendered irregular either by a greater extent of disunion taking place between some of the sepals, the intervening fissures being so much deeper than the others that the teeth become associated in two sets, giving a *bilabiate* condition (fig. 181)—or by irregularities at the base, where a shallow pouch renders the calyx *gibbous* (fig. 178), a deeper one *saccate*, and a long narrow pouch forms what is called a *spur*. In *Pelargonium* this spur adheres to the peduncle.

In some instances a tubular development of the receptacle or flower-stalk simulates the spur of the calyx.

Fig. 182.

Fig. 181.

Fig. 183

Fig. 184.

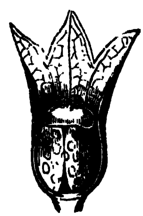


Fig. 181. Bilabiate calyx of *Salvia*.
Fig. 182. Floret of *Scabiosa*, the limb of the calyx replaced by bristles (*pappus*).
Fig. 183. Fruit of *Cichorium*, crowned by the persistent calyx represented by a circle of spines (*pappus*).
Fig. 184. Section of the persistent calyx, enclosing the ripe capsule, of *Hyoscyamus*.

The Pappus.—The free portion of the calyx of Compositæ, Dipsaceæ, and Valerianaceæ exhibits a very aberrant condition by appearing in the form of scales, bristles, or feathery or simple

hairs, constituting what is called the *pappus* (figs. 182, 183). In *Centranthus* the limb of the calyx is undeveloped when the flower opens, but expands during the ripening of the fruit into a crown of feathered processes. It is doubtful whether the pappus is not in some cases a series of mere epidermal growths or *trichomes.*

Duration.—The *duration* of the calyx varies much. In the Papaveraceæ it is *caducous*, falling off when the flower opens; if it falls with the corolla soon after fertilization of the ovules, it is *deciduous*; very frequently it is *persistent* during the ripening of the seeds, as in Labiatæ, some Solanaceæ (fig. 184), Compositæ (fig. 183), &c.; the upper part sometimes separates by a circular slit, leaving the base, as in *Datura Stramonium*; occasionally it grows during the maturation of the fruit, and is then *accrescent*, forming in *Physalis* and *Trifolium fragiferum*, for example, a vesicular envelope to the fruit. In the Marvel of Peru and other plants it is *marcescent*, remaining and growing into a firm envelope of the fruit.

Further details respecting the characters of the calyx are given under the head of the *Perianth.*

The Corolla.—The corolla is composed of all the leaf-like organs or floral envelopes situated between the calyx and the stamens; these are individually called *petals*, and may exist in one or more circles. Where many circles exist, the inner organs often become stunted or deformed, and more or less resemble barren filaments or abortive stamens (*Nymphæa*). Each petal, under ordinary circumstances, intervenes or alternates between two sepals.

The petals are either distinct, and then the corolla is called *dialypetalous* or *polypetalous*; or they are more or less coherent or inseparate, and the corolla is *gamopetalous, sympetalous*, or *monopetalous.*

When more than one circle of petals exists, the corolla is multiple or double; this is normal in certain plants, but is very liable to occur from transformation of stamens, &c., or from actual multiplication of whorls, as in cultivated flowers of the Rose, *Camellia, Ranunculus, Anemone*, &c. The petals are usually direct outgrowths from the thalamus, but sometimes they appear not to be autonomous parts but secondary outgrowths from the stamens, as in some Mallows, Primroses, &c.

The Petals.—Although petals frequently depart more than ordinary sepals from the character of true leaves in colour and texture, they present greater resemblance in some respects, since they frequently have a more or less developed petiolar region, which is sometimes of considerable length, at other times a mere thickened point; and they are commonly articulated to the receptacle. The petiolar portion of the petal is called the *claw* (*unguis*), the expanded portion the *limb* (*lamina*) (fig. 185). Petals are likewise more frequently cut at the margins, as in the fringed petals of Pinks and the laciniated petals of *Lychnis Flos-Cuculi*, or they are deeply

divided into lobes, as in many Caryophyllaceæ (fig. 186) and the pinnatifid petals of *Schizopetalum*, &c.

Fig. 185.

Fig. 186.

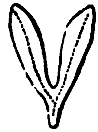


Fig. 187.

Fig. 185. Petal of *Dianthus*, fringed and stalked. Fig. 186. Bilobed petal of *Alsine media*. Fig. 187. Spurred petal of *Aquilegia*.

Forms of Petals.—The forms of petals resemble many of those indicated for simple true leaves; in addition to which others occur presenting curved surfaces: these are called simply *concave*, *navicular* or boat-shaped, *cochleariform* or shaped like the bowl of a spoon, &c.; or they may have basal pouches, and be *gibbous*, *saccate*, or *spurred* (fig. 187). Others have peculiar appendages above, such as the *crests* in *Polygala* and the *strap-like* inflexed points in the petals of the Umbelliferæ.

The term *nectary* is vaguely employed to indicate certain structures of varying character intermediate in position between the petals and the stamens, and different in aspect from both.

Petals are ordinarily of delicate structure and coloured, whence we derive the term *petaloid*; but they vary in texture from a membranaceous to a thick and fleshy condition, such as we see in *Magnolia*, *Nymphæa*, &c.

Polypetalous Corollas are *regular* when the petals are equal and symmetrically arranged; the individual petals may be themselves either symmetrical or oblique, provided they are all alike.

Some of them have received special names, such as:—the *rosaceous*, where there are five spreading petals; the *liliaceous*, where six petals spread gradually from a funnel-shaped origin; *caryophyllaceous*, where five petals have long erect claws from which the limbs turn off at a sharp angle; *cruciform*, where four such long-clawed petals with horizontal limbs stand in the form of a cross, as in the Wallflower, &c. Slight degrees of *irregularity* arise from some petals growing larger than others, as in the case of the outer petals of the outer flowers of the corymbs of *Iberis*, those of the umbels of *Umbelliferæ*, &c.; but more striking irregularity results from unlikeness of the petals and disturbance of symmetry in their insertion or point of emergence. The imperfect corolla of

Aconite (fig. 188) is an example of this; and a still more important case occurs in the *papilionaceous* corolla of *Leguminosæ* (figs. 191–193), which is composed of five petals, of which the posterior, the *vexillum* (fig. 192, *a*) or standard, the largest, usually symmetrical in form, is placed transversely; the two lateral (fig. 192, *b*, *b*), mostly oblique in form and small, forming the *alæ* or wings, stand right and left, with the edges fore and aft; and the two anterior (fig. 192, *c*, *c*), also small and oblique, often coherent in front, and forming the *carina* or *keel*, also stand with their edges forward.

Fig. 188.

Fig. 189.

Fig. 190.

Fig. 188. Flower of *Aconitum* with the sepals removed, showing the two hammer-headed posterior petals (or nectaries), with lateral and anterior scale-like petals, outside the numerous stamens.
Fig. 189. Bilabiate scroll-like petal (or nectary) of *Helleborus*.
Fig. 190. Floret of Composite, with inferior ovary surmounted by scaly pappus and tubular corolla.

Examples occur in the large order Leguminosæ of almost every modification of the papilionaceous corolla, approaching to regularity in *Baptisia* for instance, and still more in *Cassia*. Irregular corollas exist also in the Fumariaceæ, in *Viola*, Balsaminaceæ, *Pelargonium*, *Tropæolum*, and very many other plants.

Fig. 192.

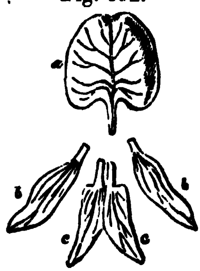


Fig. 191.

Fig. 193.

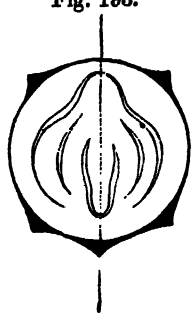


Fig. 191. Papilionaceous corolla of Pea.
Fig. 192. The separated petals: *a*, vexillum; *b*, *b*, alæ; *c*, *c*, carina.
Fig. 193. Ground-plan of floral envelopes, showing the coherent sepals and æstivation of the petals. The central line shows that the flower may be symmetrically divided into two equal halves.

Gamopetalous Corollas have a *tube*, *throat*, and *limb* like the gamosepalous calyx; and similar terms are used to indicate the more common *regular* forms, such as *tubular* (fig. 190), *campanulate* (fig. 194), *funnel-shaped* or *infundibuliform* (fig. 195), *urceolate* (fig. 196), &c., a few others being requisite for the corolla, more especially such as *rotate*, when the tube is extremely short and the limb spreads at a right angle (*Anagallis*), *hypocrateriform* or *salver-shaped* when a similar limb turns off from a long slender tube (*Jasminum*, *Phlox*) (fig. 197), &c.

Irregular gamopetalous corollas often furnish important systematic characters; and several of the forms or classes of forms have special technical names.

The *ligulate* corolla is tubular at the base; but disunion soon occurring at one sinus, the limb is turned off to one side in the shape of a flat ribbon or strap, on the margin of which occur more or less distinct teeth

Fig. 194.

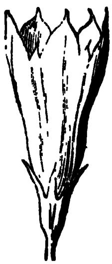


Fig. 195.

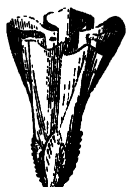


Fig. 196.

Fig. 197.

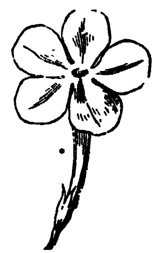


Fig. 194. Campanulate corolla of a Gentian.
Fig. 195. Funnel-shaped corolla of *Convolvulus*.
Fig. 196. Urceolate corolla of a Heath.
Fig. 197. Salver-shaped corolla of *Phlox*.

indicating the five component petals (fig. 198); this is especially found in the ray *florets* of Compositæ: a modification with the tube and limb wider in proportion to the length occurs in Lobeliaceæ. The *labiate* or *bilabiate* corolla of the Labiatæ (fig. 199) is formed by the two upper petals of the limb, which are scarcely at all separated, and stand apart from the three lower or anterior petals, which also are only partially separated, forming a lower lip opposite the upper one and projecting forward from the *throat* of the corolla: sometimes the upper lip is concave, and is then termed *galeate*, or helmet-like; in other cases (*Ajuga*) it is almost abortive.

Almost every modification of this form occurs in the Labiatæ, approaching to an almost regular tubular corolla in *Mentha*. This form occurs also in the florets of some Compositæ and in those of various Dipsaceæ, where, however, the upper lip is 3-lobed and the lower 2-lobed; in the Honeysuckle the upper lip contains four petals, and the lower is formed by a solitary one. *Veronica* has an irregular corolla intermediate between *bilabiate* and *rotate* (fig. 200).

The *personate* or *mask-like* corolla is rather indefinite in form: the type of it occurs in *Antirrhinum* (fig. 201), which approaches the *labiate* form; but the throat is closed by a gibbous projection (forming the *palate*), giving the front view the appearance of a mask with a broad-lipped mouth.

Fig. 198.

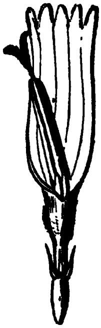


Fig. 199.

Fig. 200.

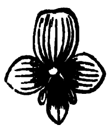


Fig. 201.

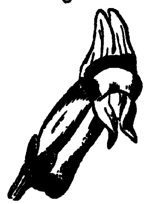


Fig. 198. Ligulate corolla of Composite, with "inferior" ovary and scaly pappus.
Fig. 199. Bilabiate corolla of *Salvia*, of five united irregular petals.
Fig. 200. Corolla of *Veronica*, bilabiate in structure, but the four segments spreading like a rotate corolla, and with two stamens.
Fig. 201. Personate corolla of *Antirrhinum*.

This is accompanied by a similar *gibbous* condition of the base of the tube in *Antirrhinum*, and by a spur in the same situation in *Linaria*. Aberrant forms of this type occur in *Calceolaria* (fig. 202), *Utricularia*

Fig. 202.

Fig. 203.

Fig. 204.

Fig. 205.

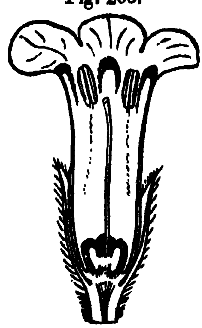


Fig. 202. Personate corolla of *Calceolaria*.
Fig. 203. Personate corolla of *Utricularia*.
Fig. 204. Petals of *Lychnis*, with scales at junction of stalk and blade.
Fig. 205. Section of a flower of a Boraginaceous plant, showing scales in the throat, between the stamens, superposed to the petals.

(fig. 203); and it runs into the *labiate* form by such corollas as those of *Melampyrum* &c., becoming tubular in *Digitalis.* Forms allied to this occur commonly in Bignoniaceæ, Gesneraceæ, Acanthaceæ, &c.

When the throat of a bilabiate or irregularly lobed tubular corolla is widely opened, it is called *ringent* or gaping.

Outgrowths from Petals.—Petals when distinct sometimes exhibit appendages on the inner face which have been interpreted as stipulary, as in *Lychnis* (fig. 204); in *Ranunculus* we find a minute *scale* at the base, and in *Parnassia* a largish scale, simple or divided, and of glandular character. In gamopetalous corollas we often find a *circle* of *scales* in the throat, either free or confluent into what is called a *coronet* (*corona*), sometimes developed so far as to produce a long tube projecting from the throat. In other cases there is simply a ring of hairs in the throat (*Mentha*, &c.). In most cases the scales are in front of the lobes of the corolla (fig. 205), rarely alternate and opposite to the sinuses.

Examples of circles of scales in the throat occur especially in the Boraginaceæ (*Myosotis*, *Symphytum*, &c.), in *Cuscuta*, &c. In *Narcissus poëticus* and other species the corona is a complete ring, while in *N. pseudo-narcissus* (the Daffodil) it forms the deep yellow tube projecting from the centre. Some authors attribute these structures to *chorisis*, others regard them as representing a circle of regular stamens in an abortive condition; and the alternate scales of *Samolus* may represent an abortive circle of stamens, as this would restore the symmetry of the flower. Usually, however, they are mere outgrowths from the petals, formed by *enation* at a late stage of development.

These structures, by a confusion of terms, have been called *nectaries* and nectariferous scales. The terms *scale* and *coronet* are more exact and convenient.

Duration.—The corolla is *caducous*, *deciduous*, or *persistent*, like the calyx. Occasionally it falls away in part by a circular slit, as in *Orobanche* and *Rhinanthus.*

Fig. 206.

Opening flower of the Vine. The petals, cohering by their tips, fall off in one star - shaped piece.

In *Vitis* the caducous *corolla* separates from the receptacle at the bases of the petals, which cohere above and fall off like a little star when the flower opens (fig. 206). The corolla is mostly *deciduous*; it is persistent in *Campanula.*

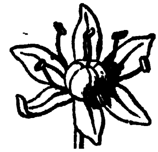
In withering, the petals are sometimes closed (*occlusa*), as in *Echeveria*, spreading as in *Boussingaultia*, *reflexed* as in *Begonia*, *crisped* as in *Pavia*, pulpy as in *Tradescantia*, *circinate* as in *Capparis*, *recircinate* as in *Mesembryanthemum*, and *conduplicate* as in some species of *Ornithogalum.*

The Perianth, in a special sense (see p. 104), consists of the floral envelopes when composed of two circles of similar organs, so that, except in position, there is no difference to be seen between

calyx and corolla, as in the Tulip; or of one circle, then always called a calyx whatever its colour, as in Monochlamydeous flowers.

A large number of the Monocotyledonous orders possess a *petaloid perianth*; that is, there are two circles of petaloid organs, which, from their resemblance, or actual coherence, have the appearance of a single hexamerous whorl. This perianth may be *regular* (fig. 207) or *irregular*, like the normal calyx and corolla; it may be *polyphyllous* or *gamophyllous*; and the outer circle may differ to some extent from the inner in form, size, and colour, without other irregularity. The forms are described by the same terms as those used for the calyx and corolla.

Fig. 207.



Regular 6-merous petaloid perianth of *Allium*, enclosing six hypogynous stamens and a central 3-lobed pistil with a single style.

We have a regular polyphyllous perianth in the Tulip and Lily; a regular gamophyllous perianth in *Hemerocallis*, *Convallaria*, *Tamus*, &c.; a regular polyphyllous perianth with unlike circles in *Iris*; and irregular polyphyllous perianths in Zingiberaceæ, Orchidaceæ, &c.

Perianth of Orchids.—The irregular perianth of Orchidaceæ (figs. 208 & 209) requires especial mention, as the Order is very large and the characters of the perianth peculiar. There are three outer organs (*a*, *a*, *a*), more or less alike, and usually smaller than the inner; of the inner, the lateral (*b*, *b*) are smaller than the posterior (*b'*), called the lip (or *labellum*), which is often excessively developed, and even divided into regions which receive separate names; in many of our native Orchids it possesses a spur (fig. 208, *b**).

Fig. 208.

Fig. 209.

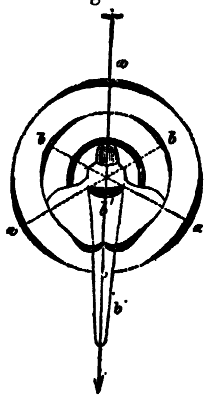


Fig. 210.

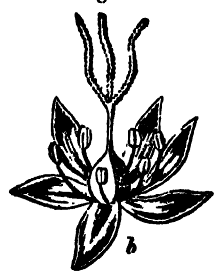


Fig. 208. Flower of an Orchis, seen in its natural position, where, owing to the twisting of the inferior ovary, the anterior or inferior part is above and the posterior below. *a*, *a*, *a*, represent the outer parts of the perianth or petals; *b*, *b*, the lateral petals; *b'*, the labellum, prolonged behind at the base into a spur, *b**.

Fig. 209. Ground-plan of the flower, with the same references.

Fig. 210. Flower of *Luzula*: *b*, the 6-merous scaly perianth, surrounding six hypogynous stamens and a central 3-cornered pistil with a single style and three stigmas.

Perianth of Palms.—The perianth of the Palms, of Juncaceæ (fig. 210), and other Monocotyledons is composed of scale-like, fleshy or membranous organs, either free or confluent, approaching to the condition found in the Glumiferæ.

Monochlamydeous Perianth.—The perianth of the Monochlamydeous Dicotyledons is very varied in form, texture, and colour. It may be *gamophyllous* or *polyphyllous*, and then *regular* (fig. 211) or *irregular* (fig. 212), and, moreover, *petaloid* or *sepaloid*. It is reduced to the lowest state in the Poplar (fig. 213), where it is a mere membranous cup; and it is absent in the allied genus *Salix*, as also in the Ash (fig. 214), which are therefore *achlamydeous*.

Fig. 211.

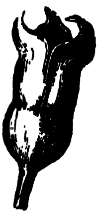


Fig. 213.

Fig. 212.

Fig. 211. Regular perianth of *Asarum*.
Fig. 212. Irregular perianth of *Aristolochia Clematitis*.
Fig. 213. Flower of the Poplar: ♂, from a male catkin; ♀, from a female catkin; each with a cup-shaped perianth.

A gamophyllous, coloured, regular perianth exists in Thymelaceæ (*Daphne*); the dull-coloured gamophyllous perianth of *Aristolochia* is irregular (fig. 212). The gamophyllous sepaloid perianths of *Ulmus* and *Castanea* (figs. 215, 216) &c. are regular; the polyphyllous sepaloid perianth of Urticaceæ is also regular. In *Polygonum*, the regular gamophyllous perianth is partially petaloid, while, in the same order, *Rumex* and *Rheum* have a double circle of unequal, wholly sepaloid organs.

Glumaceous Perianth.—The perianth of the Glumiferous Monocotyledons requires special mention.

In the Grasses, as already mentioned, the flowers are borne in *spikelets*, associated in spikes, or panicles. A spikelet of the Oat, for example (fig. 217), exhibits at its base a pair of green membranous bracts, the *glumes* (*a, a*) more or less enclosing all the inner parts: these are regarded as bracts, or *spathes*; and within them are found one, two, or more flowers. The flowers succeed one another alternately on a *rachis*; and each is invested by a bract resembling the glumes, called the *flowering glume* or the *outer palea* (figs. 217–219, *b*): within this is an inner scale

forked at the top, and often with two distinct principal ribs; hence it is regarded as composed of two confluent scales. This is called the palea or the *inner palea*. These scales often bear a projecting bristle (*awn*,

Fig. 215.

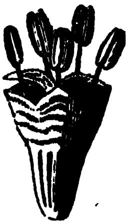


Fig. 214.

Fig. 216.

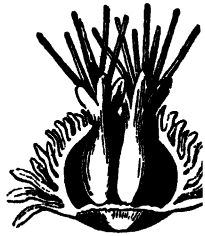


Fig. 214. Naked flower of the Ash (*Fraxinus excelsior*).
Fig. 215. Flower of the Elm (*Ulmus*), with a regular 5-toothed perianth.
Fig. 216. Involucre or young cupule of the Chestnut (*Castanea vesca*), with two female flowers, each having a regular perianth.

arista) at the top or on the back (fig. 218, *b**). Within the pale (fig. 219) occur two or in some Grasses three little hypogynous scales (*lodiculæ*, *x*, *x*), corresponding to petals; and to them succeed the stamens and pistil.

Fig. 217.

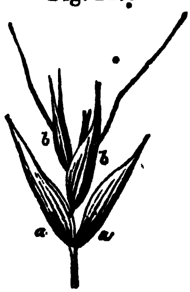


Fig. 219.

Fig. 218.

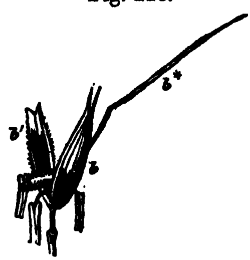


Fig. 217. Spikelet of the Oat: *a*, *a*, glumes; *b*, *b*, the flowering glumes or outer pales of the two florets.
Fig. 218. One floret detached and opened: *b*, the outer pale (with an awn *b**); *b'*, the inner pale.
Fig. 219. The same, magnified, with the outer pale removed: *b*, the inner (double) pale; *x*, *x*, the *lodiculæ* or hypogynous scales representing the petals, within which are the three stamens and the ovary, with its double feathered stigma.

The hypogynous scales are three in number in *Stipa*, restoring the symmetry. The upper glume is sometimes abortive, as in *Lolium*, while in *Nardus* both are absent. In *Alopecurus* only one pale is developed. The spikelet often contains one or more imperfect flowers.

The perianth of Cyperaceæ, where it exists, presents a still simpler

condition, analogous to that in the Amentiferous Dicotyledons, and in some cases is abortive. In *Scirpus* (fig. 220) it consists of a circle of bristles; in *Eriophorum* it is a tuft of hairs, which grow out into a "lock" of cotton as the fruit ripens. In *Carex* (fig. 221) there is an urceolate or

Fig. 220.

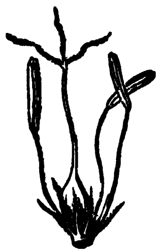


Fig. 221.

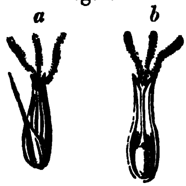


Fig. 220. Flower of *Scirpus*, the essential organs surrounded by a circle of bristles.
Fig. 221. Female flower of *Carex*: *a*, the *perigynium*, or perianth, in the axil of a bract; *b*, the tubular *perigynium* cut open vertically, to show how it surrounds the pistil.

inflated tubular *perigynium* or *utriculus* surrounding the pistil of the fertile or female flower, which stands in the axil of a bract, and which is itself composed of the union of two scales or bracteoles. *Cyperus*, *Cladium*, &c. have the essential organs naked in the axil of a bract.

Sect. 9. The Essential Organs of Flowers.

The essential organs of flowers consist of an *andrœcium* or assemblage of *stamens*, and of a *gynœcium* or *pistil* consisting of *carpels* with their contained ovules. The andrœcium and the gynæcium are both present in *perfect* flowers, although these latter may be *incomplete*, from the absence of floral envelopes. In *diclinous* or *unisexual* flowers the stamens or pistils exist alone, and the flowers are consequently *imperfect*.

Organs *morphologically* intermediate between petals and stamens occur, not only normally, as in the flowers of *Nymphæa*, but such structures are very common in monstrous double flowers, bearing anthers or polliniferous lobes upon the borders of petals. The morphological connexion is also kept up by the existence of sterile filaments or stamen-stalks, which, like the filaments of perfect stamens, may exhibit a *petaloid* character.

In monstrous flowers sometimes imperfect organs present themselves, partaking of the outward characters both of stamens and carpels.

The Disk.—Abortive organs, referable either to the corolline or the staminal circles or excrescences therefrom, have been already referred to; but it is desirable to notice more particularly the conditions of those structures which are commonly described under the name of *disk* (see p. 100).

The simplest state is that of one or more glandular papillæ upon the receptacle, as in the Cruciferæ. In the Crassulaceæ (*Sedum*, *Sempervivum*) we find a circle of glandular bodies outside the carpels and between these and the stamens. In *Cobæa*, the Vine, and other flowers there is a five-lobed hypogynous disk, the stamens being inserted outside or between the lobes. In *Citrus* (fig. 222) the disk forms a perfect ring round the ovary. In *Gaultheria* there is a double circle of scales between the stamens and the ovary. On the other hand, in *Vinca* there are two glands, alternating with the two carpels of the ovary. The study of these structures is very interesting in regard to the reduction of irregular flowers to regular types. Some of the structures are rudimentary petals or stamens; and in other cases they are referable to developments of the receptacle or *torus* itself (p. 100).

Fig. 222.

Flower of *Citrus* with the petals and stamens removed, showing the calyx and the annular disk surrounding the ovary. In this case the disk is an outgrowth from the receptacle.

The Andrœcium.

The Stamens taken collectively form the *Andrœcium*. The essential character of a stamen is, that it is that organ in which are formed the *pollen-grains*, the bodies by means of which the fertilization of the ovules is effected. A completely developed stamen (fig. 223) exhibits two principal regions, the *filament* or stalk (*a*), corresponding to the petiole of a leaf, or, as Clos thinks, to the midrib of a petal; and the *anther* (*b*), corresponding to the blade of a leaf. The anther is a hollow case containing pollen, and is therefore the only essential part of the organ: the filament may be wanting or merely rudimentary; and the anther then remains *sessile*, like a leaf-blade when the petiole is not developed. The normal position of the stamens is between the petals and the pistil; each stamen, under ordinary circumstances, intervenes between two petals or is *alternate* with them, and therefore *superposed* or opposite to a *sepal*. In *Naias* and *Typha* it is supposed that the stamen is axial and not foliar.

The base of the filament, or of the so-called sessile anther, is usually *articulated* to the receptacle when these organs are *free*; but this condition is more or less disguised when the stamens are adherent to or inseparate from the calyx, corolla, or ovary.

Staminodes or sterile filaments, *i. e.* such as are devoid of anthers, occur in many flowers in regular circles; and not unfrequently one or more stamens exist in this condition in unsymmetrical flowers. Sometimes these staminodia are reduced to mere *scales*, as in the odd stamen of *Scrophularia* (fig. 224), or to glandular papillæ, as in the flowers of many Cruciferæ.

Filament.—The filament, in its usual condition, is a slender thread-like stalk to the anther, and in this state is termed *filiform*. Sometimes it is almost hair-like, and incapable of supporting the

Fig. 223.

Fig. 224.

Fig. 225.

Fig. 226.

Fig. 223. A stamen: *a*, the filament; *b*, the anther.
Fig. 224. Corolla of *Scrophularia* laid open, showing the four didynamous stamens and the posterior barren one, or staminode.
Fig. 225. Stamen of *Allium*, with a trifid filament.
Fig. 226. Stamen of *Paris quadrifolia* with prolonged connective.

weight of the anther, when it is *capillary*, as in the Grasses; while it is still more frequently thick at the base, diminishing gradually upwards, so as to become *awl-shaped* or *subulate*. In a few instances (*Urtica*) it is *moniliform*, or like a row of beads. In other cases it is more or less expanded into a *petaloid* condition, as in *Erodium*; in *Campanula* it is expanded in this manner at the base. *Ornithogalum* has the filament *dilated* in this way throughout. The dilated filament sometimes exhibits *divisions*: in *Crambe* it is forked at the summit, the anther standing on one point; in *Allium* (fig. 225), *Alyssum calycinum*, *Ornithogalum nutans*, &c. the filament terminates in three teeth, the middle one bearing the anther; and in *Allium sativum* one of the lateral teeth forms a kind of tendril.

Branched Stamens.—In some plants, as in Mallows, some Myrtaceæ, *Hypericum*, &c., the stamens are very numerous and are arranged in fascicles. The study of the development of these fascicles shows that they are originally single organs, which become subsequently divided or branched, so that the fascicle of stamens in such a case may be compared to a divided or compound leaf. Some of the divisions may be petaloid and sterile, others antheriferous.

Appendages of other kinds are also met with, such as a pair of *glandular processes*, standing like stipules near the base, in Lauraceæ (fig. 233), a single *spur* in Rosemary; while in *Borago* the

filament appears to arise on the face of a scale-like body, and in *Simaba* and *Larrea* it stands at the back of an analogous scale.

The scale-like organs situated at the base of filaments, or connected with fascicles of stamens (*Tiliaceæ*), are by some regarded as furnishing evidence for the doctrine of *chorisis*; but they are more probably merely barren lobes of compound stamens.

The Anther—its parts.—The anther has a typical form, which is subject to very great modification in different cases. It corresponds to the microsporangium of some of the higher Cryptogams. A *regular* anther (fig. 223, *b*) is an oblong body, divided perpendicularly into two *lobes*; the division is usually marked by a furrow on the *face*, and a ridge on the *back* (or *dorsum*). The central region, which is solid and represents the midrib of a leaf, is called the *connective*; the *lobes* are hollow dilatations of the lamina, and contain the *pollen*. At each border, usually rather toward the *face*, is often to be seen a vertical line, called the *suture*, indicating the place where one class of anthers split open to discharge the pollen.

Attachment to the Filament.—The anther is attached to the filament in several ways: if the filament runs directly without interruption into the base of the connective, like the stalk of an ordinary leaf, it is said to be *innate* or *basifixed*; if the filament runs up the back of the anther as it were, so that the latter is more or less free at the base, the anther is *adnate* or *dorsifixed*; if the filament is attached by a slender apex to about the middle of the back of the anther, the latter is *versatile*. In some cases the anther is *pendulous* from the apex; it is then sometimes called *apicifixed*. In the Tulip, the capillary point of the filament runs up into a conical pit in the base of the connective.

Modifications.—The modifications of the anther result from various causes—from development of the connective, from the presence of appendages, from variation of form of the anther-lobes, and from special conditions of the internal cells; and there are also important differences in the manner of bursting, or *dehiscence*, for the discharge of the pollen.

The Connective.—The connective is normally a solid rib, running up the middle of the anther. If the lobes of the anther extend upward or downward beyond it, the summit or base of the anther (or both) becomes *emarginate*. On the other hand, the summit of the connective is prolonged in a membranous form in *Viola*, and also in the Compositæ. In *Paris* (fig. 226) the apex is lengthened into a point, also in *Asarum*, *Magnolia*, &c.; in *Xylopia* into a fleshy mass; in the Oleanders into a feathered process, &c. In two of the stamens of *Viola* the base of the connective has petaloid spur-like appendages; and still more remarkable states occur in the Melastomaceæ.

At other times the connective expands transversely, so that the lobes become more or less separated; in such cases it may be *ovate, orbicular*, &c. (*Melissa*, the Lime-tree, &c.). This is especially the case with the lower part; and examples may be found illustrating this point, forming a series from the state where the bases of the lobes are but slightly separated, to that in which they are inclined together at the summit at an angle of 45° (*Vitex*); or, further, the bases are carried out and up till they are horizontal, as in *Stachys, Prunella*, &c.; while in other instances this goes so far that the connective grows out into two distinct arms from the summit of the filament, bearing the solitary anther-cells at the tips: in *Salvia* (fig 227) one of the lobes is abortive, and represented by a petaloid plate.

Fig. 228.

Fig. 227.

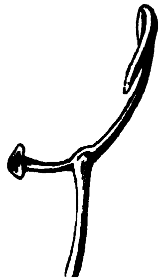


Fig. 229.

Fig. 227. Stamen of *Salvia officinalis*, with a half-anther containing pollen and the other half barren, separated by the bifurcation of the connective from the summit of the filament.
Fig. 228. Group of stamens with sinuate anthers, of the male flower of a Gourd.
Fig. 229. Stamen of *Vaccinium uliginosum*, with spur-like appendage and porous anthers.

Anther-lobes.—The lobes of the anther are commonly oblong; in the Grasses they are *linear*; but they vary with the form of the connective, and are sometimes *lunate* or *reniform*. In the Cucurbitaceæ they are remarkably convoluted (*sinuate*) into a flat scroll-like form (fig. 228). Not unfrequently they are attenuated upwards into free points, as in *Vaccinium* (fig. 229); in the Melastomaceæ the two lobes become confluent into a tubular process at the summit; while appendages are occasionally met with at the base of the lobes, as in *Erica* (fig. 230), &c.

Anther-loculi.—The lobes of most anthers exhibit internally four *cells* (*thecæ* or *loculi*) in the early stages of development, each lobe being divided into two by the *septum* extending from the connective to the suture (fig. 231). The septum (the *placentoid* of Chatin) is more or less destroyed during the maturation of the pollen in

most cases, leaving the anther *two-celled*, or *bilocular* (fig. 232). In some cases the internal substance of the connective is likewise absorbed, producing a true *unilocular* anther, as in *Alchemilla* and in Malvaceæ. In other cases the four cells are retained perfect,

Fig. 230.

Fig. 231.

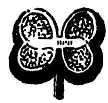


Fig. 232.

Fig. 233.

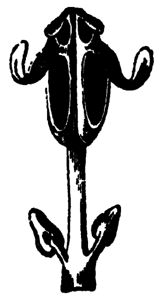


Fig. 230. Stamen of *Erica cinerea*.
Fig. 231. Section of an anther, its two lobes still divided into two cells by the *septa* reaching from the connective to the *sutures*.
Fig. 232. Section of a bilocular anther (the septa have been absorbed).
Fig. 233. Stamen of *Laurus Persea*, having a 4-celled anther with opercular dehiscence, and two lobes at the base of the filament representing divisions of a compound stamen.

as in the *quadrilocular* anthers of *Butomus*, where they are parallel, and of some Lauraceæ, where they become *oblique* so that the summits are all turned towards the face. The *dimidiate* unilocular anthers of *Gomphrena* and *Salvia* are so called from being only halves of anthers in which one lobe is abortive or suppressed. Anomalous one-celled anthers occur in *Polygala*. The unilocular lateral anthers of the diadelphous stamens of Fumariaceæ are *dimidiate*.

Dehiscence.—When the anthers are mature, the cells or loculi open and discharge the pollen. This dehiscence takes place in different ways; it may be *sutural*, *porous*, or *opercular*. *Sutural* dehiscence is the opening of the walls by splitting down vertically at the sutures, which may be *extrorse*, *introrse*, or *lateral* (see p. 126). A transverse slit is formed in the unilocular anther of *Alchemilla*, in *Lavandula*, and in *Lemna*. *Porous* dehiscence is where definite orifices are formed at some point of the wall of the loculus, as at or near the summit in *Solanum*, Ericaceæ (figs. 229, 230), &c. *Opercular* dehiscence results from the partial separation of a portion of the wall of the loculus, in the form of a kind of lid, as in the Berberry, where the front of each cell splits off at the sides and base, and turns back as if hinged at the top.

In the Lauraceæ (fig. 233) we find either two or four little lids of this kind, opening the two or four cells of the anthers.

If the anther be considered the equivalent of a leaf with infolded margins, then the groove between the two lobes would represent the margins of the leaf; but there is reason to suppose that no such infolding really occurs, but that two pollen-sacs are formed on either side of the connective without any involution of the margin.

Stamens of Gymnosperms.—The stamens of the Gymnospermia present remarkable conditions, which require separate notice.

Among the Coniferæ (see that order) the stamens of *Pinus* constitute the entire male flowers, and are conjoined into male cones, each anther forming a scale of the cone; they are bract-like plates, bearing on the lower face two parallel anther-lobes (bursting longitudinally or irregularly), beyond which the connective extends more or less as a scale-like process. In *Cupressus* the form of the anther is excentrically *peltate*, the lobes, three or four in number, standing under the overhanging connective; and it is similar in *Juniperus* and *Thuja*. In *Taxus* the *peltate* connective is more symmetrical, and radiately grooved above, having from three to eight vertical anther-lobes beneath: some authors regard this as a group of monadelphous stamens.

In the Cycadaceæ (for illustration see that order), where the anthers are scattered in large numbers over the lower face of the scales of the male cones, they occur mostly in the form of groups of four simple anther-lobes, with longitudinal dehiscence and arranged in the form of a cross. These are mostly described as parcels of unilocular anthers.

Number of the Stamens.—The stamens, taken collectively, present a number of characters, which have received technical names. The number of stamens in a flower is indicated by the terms *mon-androus*, *di-androus*, &c.; when more than twelve exist, the term *poly-androus* is employed. Upon the number of the stamens the Linnean classification was partly founded. When the number of the stamens is equal to, or some multiple of, the number of petals in the corolla &c., the flower is *isostemonous*; when the number is different (as in Scrophulariaceæ &c.) the flower is *anisostemonous*. When there is one whorl of stamens in the normal position, the term *haplostemonous* is employed; *diplostemonous* is used where there are two whorls, and *obdiplostemonous* where there are two rows of stamens, the outer superposed to the petals.

Relative length.—Two cases of inequality of length of the filaments are distinctly named, viz. the *didynamous* condition (figs. 234 & 235), when there are two pairs of stamens, one pair longer than the other, characteristic of many irregular Monopetalous flowers (Labiatæ, Scrophulariaceæ, &c.); and *tetradynamous*

(fig. 236), when there are four long stamens and two short ones, characteristic of the Cruciferæ. When the stamens are of unequal length in the same flower, or in different flowers of the same species (*e.g.* Primrose), the condition is called *dimorphic*, and has reference to the mode of fertilization to be hereafter mentioned.

The term *included* is employed to denote that the stamens do not reach beyond the corolla; *exserted*, that they are protruded from it; while *declinate* means that the exserted stamens are all curved over to one side.

Cohesion, etc.—The stamens are subject to apparent confluence or cohesion, like the other organs. If the filaments are only

Fig. 234.

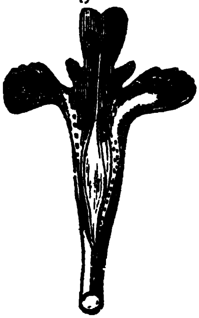


Fig. 236.

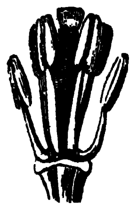


Fig. 235.

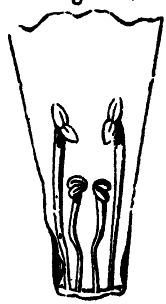


Fig. 234. Corolla of *Glechoma*, laid open to show the didynamous stamens.
Fig. 235. Corolla of *Digitalis*, laid open to show the didynamous stamens.
Fig. 236. Tetradynamous stamens of the Wallflower surrounding the pistil, the floral envelopes being removed.

partially separated so that they form a tube surrounding the

Fig. 237.

Fig. 238.

Fig. 239.

Fig. 240.

Fig. 237. Monadelphous stamens of *Malva*.
Fig. 238. Diadelphous stamens of Leguminosæ.
Fig. 239. Ground-plan of a Papilionaceous flower with diadelphous stamens 9+1 (the little circles round the solitary carpel).
Fig. 240. Triadelphous or polyadelphous stamens of *Hypericum ægyptiacum*.

style (or a column in a staminate flower of a diclinous plant) (fig. 228), the stamens are *monadelphous* (fig. 237), as in Malvaceæ, *Camellia*, &c. In Fumariaceæ they are coherent into two equal parcels, while in many Leguminosæ, of ten stamens, nine are united together and one free: these states are called *diadelphous* (figs. 238 & 239). In Hypericaceæ we have *triadelphous* (fig. 240) and *pentadelphous* states; but these, as also the state in Aurantiaceæ and various Myrtaceæ, are generally denominated *polyadelphous*, and are instances of branched stamens (p. 120).

Syngenesious signifies that the filaments are free, but the anthers coherent (fig. 241), as in Compositæ and Lobeliaceæ. *Gynandrous* indicates confluence of stamens and pistils, such as occur in Orchidaceæ, Asclepiadaceæ, *Aristolochia*, &c. (fig. 242). These terms, together with those descriptive of *adhesion* (*perigynous*, *epigynous*, &c.), have already been explained, as also the meaning of the words *monœcious*, *diœcious*, &c.

Fig. 241.

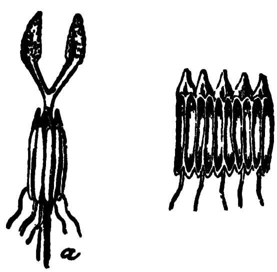


Fig. 242.

Fig. 243.

Fig. 241. Syngenesious stamens of Compositæ: *a*, the anthers surrounding the style as a sheath; *b*, the anthers removed and spread out, showing the free filaments.
Fig. 242. Section of the lower part of the perianth of *Aristolochia*, springing from the top of the inferior ovary. In the cavity of the perianth is seen the style, with the adherent anthers upon its sides.
Fig. 243. Clavate pollen-mass of *Orchis*, prolonged below into a *caudicle*, by which it attaches itself to the *rostellum* of the stigma.

Direction of Anthers.—Usually what is called the *face* of the anther is turned inwards towards the ovary, and it is then said to be *introrse*: but sometimes the reverse state exists, and the face is turned towards the floral envelopes, as in *Ranunculus*, *Colchicum*, &c., when the anthers are termed *extrorse*. Frequently the direction changes during the expansion of the flower, as in versatile anthers. (See also under Dehiscence, p. 123.)

Pollen.—The *pollen*, discharged from the anthers, consists in almost all cases of a fine powder composed of microscopic grains or cells corresponding to the *microspores* of the higher Cryptogams;

the form and appearance of the grains vary much, and will be spoken of hereafter. The pollen of the Asclepiadaceæ and Orchidaceæ, however, has a great peculiarity, in remaining permanently coherent into masses, often of a waxy character. In Orchidaceæ the *pollen-masses* or *pollinia* are either single in each loculus of the anther (as they are in Asclepiadaceæ), and then often furnished, as in *Orchis* &c., with a stalk-like process, called the *caudicle* (fig. 243), terminating in a gland-like base (*retinaculum*), by which they readily adhere to the stigma or to foreign bodies, such as insects; or the *pollinia* are two or four in each loculus, and devoid of a caudicle; sometimes the *pollinia* are numerous, and form merely a loose granular mass.

The external characters of the pollen-grains, their structure, and subsequent history will be treated of in the Third Part of this work, as they belong to the microscopic anatomy and the Physiology of Plants. The form of the pollen-grains is generally constant in the same plant; but great variations are often found within the limits of Natural Orders and sometimes in the same genus, so that, excepting the Orchidaceæ and Asclepiadaceæ, and a few other groups, they are not to be relied on as affording any very useful characters in Systematic Botany. Their size, form, and numbers are apparently in relation to their mode of dispersion by the wind or by insects.

The Gynœcium or Pistil.

Carpels.—The central essential organs of flowers, composing the *pistil*, consist, like the outer parts, of *phyllomes* or modified leaves; these constituent leaves are called *carpels*. The peculiar character of a carpel is, that it produces *ovules*, the rudiments of the seeds—usually upon the margins, but occasionally on other parts of the internal surface. In the Gymnospermia these ovules are developed upon the edges or surface of expanded carpels. In the Angiospermia, comprehending the great majority of Flowering plants, the carpels are folded up, either singly (fig. 244) or collectively, with the margins turned in so as to place the ovules in the interior of a hollow case. The case thus formed, enclosing the

Fig. 244. Fig. 245.

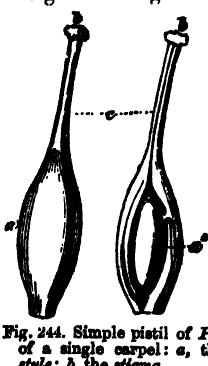


Fig. 246.

Fig. 244. Simple pistil of *Prunus*, consisting of a single carpel: *a*, the *ovary*; *c*, the *style*; *b*, the *stigma*.
Fig. 245. The same, opened, to show the *ovule* within the ovary.
Fig. 246. Cross section of the carpel of *Prunus*, showing that the ovule arises from the placenta at the confluent margins of the carpel.

ovules, is called the *ovary* (figs. 244 & 245, *a*, *a'*); the upper part of the carpel is frequently attenuated into a slender column called the *style* (*c*), at the extremity of which is a terminal glandular orifice or *stigma* (*b*, *b*), the borders of which are often more or less thickened or developed into processes of various kinds. Sometimes the *stylar* prolongation does not exist; and then the *stigma* is *sessile* upon the *ovary*.

The pistils are undoubtedly formed of carpels (carpellary leaves) in most instances. In some cases they appear to be formed by an expansion of the receptacle or axis of the flower, as in *Typha* and *Naias*; while their structure and venation are in some cases neither those of a leaf nor of an axis, but, as it were, intermediate between the two.

Phyllody.—The foundations of the doctrine that the carpels are metamorphosed leaves rest upon a very wide basis. The following observations include examples of some of the most important classes of proofs:—1. The carpel ordinarily possesses more of the character of a true leaf, as regards texture and colour, than the stamens or petals—approaching to the sepals, which we have seen to pass insensibly through the bracts into ordinary leaves. The resemblance is sometimes heightened during the development of the fruit, as we see in the legumes of some species of *Cassia*, and still more in the bladder-like pod of *Colutea*. 2. Abundant examples exist of the substitution of petals for stamens and pistils in abnormal flowers; and an almost equally common monstrosity consists in the substitution of isolated stunted green leaves for the carpels. In the Double Cherry, cultivated in shrubberies for the sake of its blossom, the stamens are generally replaced by petals, while the centre of the flower is mostly occupied by a pair of green leaves. (The single, fertile Cherry frequently has two pistils developed instead of one.) In a common monstrosity of the White Clover, the pod is usually replaced by a more or less perfect green leaf; the same occurs in garden Roses, where tufts of green leaves replace the pistils; and, in fact, examples of this kind are very abundant. 3. The more or less stunted green leaves which represent the carpels in the above-mentioned monsters frequently exhibit on their margins structures varying in character from almost perfect rudiments of ovules to cellular papillæ and leafy lobules. This is observed in the monstrous Clover, and has been especially remarked also in monstrous flowers of cultivated (forced) Tulips, of various Cruciferæ, Ranunculaceæ, Scrophulariaceæ, &c. The abnormal conditions in these cases are analogous to the normal condition in Coniferæ and Cycadeæ, the Gymnosperms, where the ovules are always naked on open carpels. 4. The production of ovules on the margins of carpels is analogous to what is seen in the development of *adventitious buds* on vegetative leaves, as in *Bryophyllum*, &c. Such buds, however, occur sometimes on the upper surface of leaves; and we find some carpels, as in *Nymphæa*, *Butomus*, &c., with ovules developed more or less extensively over the internal face. 5. The disposition or arrangement of the vascular bundles is usually that of the leaf, not that of the branch. 6. The structure, development, and mode of growth generally are those of the leaf and not of the branch. Exceptions, however, occur to the last two statements.

Placenta, Sutures.—The region of the carpel whence the ovules arise is called the placenta; and when in Angiospermous flowers the placentas are clearly and distinctly marginal, they must of course be *double*, from the meeting of the two edges; the same is true of the *stigmatic surfaces*. The line of union of the margins of carpels constitutes the *ventral suture*: the line corresponding to the midrib of the carpellary leaf is the *dorsal suture*.

An excellent example of a simple typical pistil formed of a single carpel is afforded by the legume of the Leguminosæ; as, for instance, in the Sweet-pea, where we find the ovary, with a ventral and dorsal suture, narrowed above into a short slender style, terminating in a slightly enlarged stigma. When we open the ovary, in the way it is broken in shelling peas for the table, we find the placentary margins separated at the ventral suture, each carrying away half the ovules, demonstrating clearly the double character of the placenta.

Modifications.—Pistils differ extremely in different plants, from dissimilarity in the number, degree, and mode of union of the carpels, as well as in the relative degree of development of the different regions of the carpels, and with these may be associated the peculiarities arising from adhesion of the outer circles.

Numerical relation.—The number of carpels is most frequently less than that of the organs in the outer whorls, being very frequently reduced to two, and often to one. On the other hand, multiplication of the number is met with in certain Orders, where the receptacle is generally more or less enlarged to make room for them.

A large portion of the Gamopetalous Dicotyledons, with a quinary arrangement of the calyx and corolla, and often of the stamens, have dicarpellary pistils, as Gentianaceæ, Apocynaceæ, Solanaceæ, &c. Leguminosæ with quinary flowers have a solitary carpel. The agreement of the number of carpels with the other organs is almost universal in the ternary flowers of Monocotyledons, as in Liliaceæ, Iridaceæ, Orchidaceæ, &c. Multiplication of carpels is especially frequent in the Ranunculaceæ, Magnoliaceæ, and some other Orders.

Apocarpous Pistil.—In the typical pistil above described, and which really exists in Leguminosæ (for instance), the organ, being composed of one carpel only, is *simple*. A carpel may be solitary in a flower, from suppression of the remainder of the circle; or there may be in the same flower several distinct, *i. e.* uncombined, carpels, as in Larkspur, Aconite, *Magnolia*, *Ranunculus*, *Fragaria*, &c.: in these cases the terms *multiple pistils* is occasionally used, or we may say carpels *distinct*, three, five, or numerous, as the case may be. The term *apocarpous pistil* includes both the solitary carpel and the multiple pistils. In the case of multiple pistils,

where the receptacle is flat the carpels are in *whorls*; but if the receptacle is elongated the carpels are arranged *spirally*, as in *Magnolia*.

Syncarpous Pistil.—Where, as very frequently happens, the carpels cohere together, as the stamens do in the condition called monadelphous, a *syncarpous* or *compound pistil* is formed; and as the carpels occupy the apex of the receptacle, they do not form an open organ, like the tube of filaments in *Malva* for example, but a closed case, appearing externally like a solid body, mostly with ridges and grooves on the outside, indicating its compound nature.

The union varies very much in degree; even in multiple pistils we find the carpels sometimes cohering strongly while young, and separated only as the seeds ripen; and in true compound pistils the union does not always extend to the summit of the ovarian region, as we observe in the Saxifragaceæ, where the apices of the ovaries diverge. More frequently the ovarian regions are firmly coherent; and then the *styles* may be wholly free—Pink, *Silene* (fig. 173), *Hypericum*, &c.; or united part of the way up, as in some Malvaceæ (fig. 247); or entirely, but with the stigmas distinct, as in *Geranium*, &c.; or the stigmas may also be confluent (Primulaceæ, Solanaceæ, &c.). Sometimes, however, the styles or stigmas exhibit the reverse condition, and are split into two parts, as in the styles of *Drosera*, *Euphorbia*, &c.

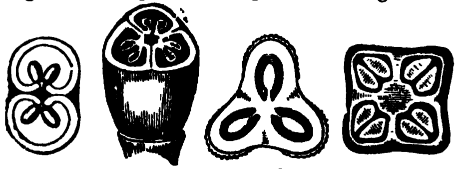
Adhesion.—The conditions arising from adhesion or want of separation have been referred to already, under the names of *superior* or *inferior calyx* or *ovary*. The condition depends on this circumstance—whether the vascular bundles for the carpellary whorl are detached at once from the axis, or whether they are held together by a sheath of cellular tissue for a time before becoming detached. They are always associated with cohesion when more than one carpel exists.

The styles, when the ovary is inferior, are either coherent, as in Iridaceæ (fig. 260), or distinct, as in the Umbelliferæ (fig. 172) and Rubiaceæ. In *Saxifraga* (fig. 171), and in some other cases, the ovary is half-inferior. When the stamens are consolidated with the pistil, the *gynandrous* condition is produced. In Orchidaceæ the filaments are inseparable from the style, forming a *column* surmounting the ovary; in Asclepiadaceæ the anthers adhere to the summit of the free compound style; in Aristolochiaceæ the filaments apparently adhere to the base of the compound style (fig. 242). (See under Aristolochiaceæ.)

Compound pistils are sometimes smooth and even on the outside, showing no sign of their compound nature, as in *Primula*, &c.; in other cases they exhibit more or less deep furrows at the lines of junction, sometimes dividing them into lobes. But the internal structure of the ovary generally indicates the number of carpels entering into its composition very plainly.

Multilocular Ovary—Placentation.—When the carpels are firmly and organically united by the surfaces of contact, we obtain the type of a *compound multilocular* or *many-celled ovary* (fig. 248)*.

Fig. 247. Fig. 248. Fig. 249. Fig. 250. Fig. 251.



Multilocular compound ovaries.

Fig. 247. Ovary, styles, and stigmas of *Malva*. Fig. 248. 2-celled ovary of Scrophulariaceæ. Fig. 249. 3-celled ovary of *Lilium*. Fig. 250. 3-celled ovary of *Commelyna*. Fig. 251. 4-celled ovary of *Fuchsia*.

In these cases the sides of the constituent carpels are folded inwards, so as to meet in the centre, and thus form partitions between the chambers or *loculi*. The placental margins of the infolded carpels are retroflexed, constituting *central* or *axile* placentas. The partitions are called *dissepiments*, and are necessarily double, being composed of the conjoined side-walls of contiguous carpels. In such ovaries the *dorsal* sutures are in the outer wall, while the ventral sutures meet in the centre (fig. 248).

Examples of this kind of ovary are furnished by Liliaceæ (fig. 249) and many other Monocotyledonous orders, by Ericaceæ, Solanaceæ, Scrophulariaceæ, &c. In some cases the ventral sutures and placentas are not directly confluent, but adhere to a central prolongation of the receptacle running up between them, as in Geraniaceæ (fig. 276), &c.

False or *spurious dissepiments* occur occasionally both in compound and simple ovaries, consisting of membranes or plates developed from the placenta or from the dorsal suture, and subdividing the originally single cavity formed by individual carpels. Thus in *Linum* the 5-carpellary ovary would have five loculi, were it not that a spurious dissepiment extends inwards from the dorsal suture to the placenta in each loculus, and divides the ovary into ten loculi. In *Astragalus* (fig. 252) the simple ovary is divided by the inflexion of the dorsal suture, and in *Datura Stramonium* a false septum is formed in each of the loculi of the ovary. The *transverse* false septa found in various Leguminous ovaries, such as *Cathartocarpus* &c., are likewise outgrowths from the walls of the carpel.

Unilocular compound Ovary.—If the carpels are not inflexed, but cohere by their contiguous margins, they form a hollow case

* The term *cell*, though commonly used, is objectionable, as leading to confusion with the cells which make up the tissues of the plant. On this account the word *loculus* is preferable.

with only a single cavity; and as the lines of junction of the carpels are on the outer wall, the placentas must stand inside those lines; in this way is formed a *unilocular compound ovary* with *parietal placentas* (figs. 253–255). There are no dissepiments: and the ventral sutures, alternating on the outer walls with the dorsal sutures, are, in such cases, like the placentas within, formed of the confluent margins of two different carpels instead of those of the same carpel.

We find almost every possible degree of transition between the *parietal* and the *axile placentas*, according as the placentiferous margins project more or less into the interior of the ovary. True parietal placentas are found in Violaceæ (fig. 254), Gentianaceæ (fig. 253), Cistaceæ (fig. 255), &c. In *Papaver* we have the margins turned-in so as nearly to reach the

Fig. 252.

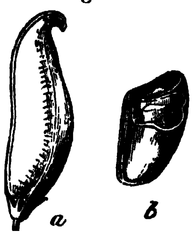


Fig. 253.

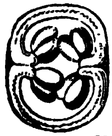
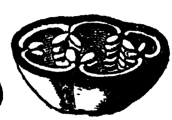


Fig. 254.

Fig. 255.



Unilocular compound ovaries.

Fig. 252. *a*, legume of *Astragalus*; *b*, cross section, showing a false dissepiment formed by the inflexion of the suture.

Fig. 253. Ovary of Gentiana.
Fig. 254. Ovary of *Viola*.
Fig. 255. Ovary of *Cistus*.

centre (as imperfect dissepiments); in some Hypericaceæ (*H. graveolens*) the originally axile placentas become parietal by separation during the ripening of the fruit, while in Cucurbitaceæ the originally distinctly parietal, although greatly inflexed, margins ultimately cohere so as to form an axile placenta.

In Cruciferæ we have an anomalous condition, where there are two double parietal placentas, but from the central line of each projects a plate passing across the cavity and forming a kind of spurious septum, called a *replum*; so that each cell contains only the two half-placentas formed by its own margins.

Free central Placentas.—In some Orders, where the walls are as in the unilocular compound ovaries above described, the placentas are found as a free column or expanded mass in the centre of the common cavity. This forms the *compound unilocular ovary with a free central placenta*. In Primulaceæ, Santalaceæ, and some other Orders, where this kind of placentation occurs, the placentas are free from their very earliest state, and are seen to be direct prolongations of the receptacle or axis within the carpels.

The appearance of a free central placenta is presented in Caryophyllaceæ by the obliteration of the partitions which pass between the outer walls and the centre of the carpels.

By Baillon a peculiar process from the placentas over the ovules is called the *obturator*; it is very conspicuous in Euphorbiaceæ.

Various modes of Placentation.—The placentas have been spoken of as *double*, on account of their origin: where only one ovule exists in a cell, it is assumed that one at least is suppressed; but this other is not unfrequently developed in the Cherry, Almond, &c. (causing the double kernels). In Leguminosæ the double placental base is so narrow that the ovules are placed one over another, and form what appears like a single line. In Larkspur, Columbine, &c. there is a distinct double row; in many cases each placenta has a double row of ovules; while axile placentas are frequently thickened and enlarged, so as to bear a large collection of ovules, closely packed. In *Papaver* the ovules exist all over the imperfect septa; in *Nymphæa* all over the sides of the dissepiments, and *not at the margins*; in *Butomus* all over the inside of the carpels, &c. Where ovules arise from the base of a carpel, either singly or in larger numbers, the placentation is called *basilar*; it is in most cases a slight modification of free central.

The Style.—The styles require no particular notice beyond the statements already made, except in regard to their irregular position in some cases. The style is really produced from the apex of the carpel; but in various Rosaceæ the ovarian part of the structure grows faster and so disproportionately that it leaves the style on one side (*lateral*) (*Fragaria*, fig. 256), and sometimes even grows out and up so much that the style, then called *basilar*, seems to arise from the base (*Alchemilla*). In the Boraginaceæ and Labiatæ (fig. 205) a similar condition of the styles exists in a compound pistil; the styles in these plants are confluent, and arise as a solitary column from a deep depression in the centre of the 4-lobed ovary, communicating with the cells near the base as in the Rosaceæ referred to. These styles of Labiatæ are called *gynobasic*. A *dimorphic* condition of the pistil especially affecting the length of the style is met with in some flowers, *e. g.* Primroses, some of which have short, others long styles, as explained under Fertilization.

The Stigma.—The stigma is either situated at the end of the style or, where this structure is wanting, it is *sessile* on the ovary. Instances of *sessile* stigmas are furnished by the compound pistils of *Papaver* (fig. 262), Nymphæaceæ, &c., where the stigmas form radiating ridges on the top of the flattened ovaries. The elongated stigmatic surfaces on the inner sides of the beak-like points of the simple pistils of *Ranunculus* and allied plants are almost to be

called sessile stigmas; and these form a transition to the long stigmatic ridges which extend down the inner sides of the styles

Fig. 256.

Fig. 257.

Fig. 258.

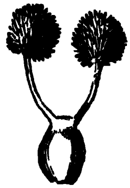


Fig. 259.

Fig. 256. Lateral style of *Fragaria*.
Fig. 257. Pistil of a Grass, with feathery stigmas.
Fig. 258. Pistil of a Grass, with penicillate stigmas.
Fig. 259. Stigmas of *Crocus*.

of most Caryophyllaceæ. When it is properly terminal it exhibits a great variety of conditions, both as regards composition and structure. Its form is sometimes associated with the method of fertilization by insects or otherwise, as afterwards explained.

Fig. 260.

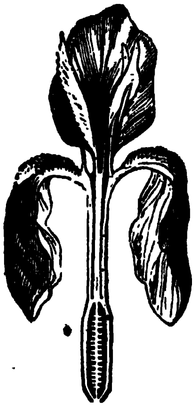


Fig. 262.

Fig. 261.

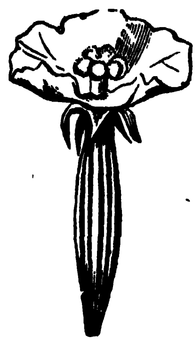


Fig. 260. Vertical section of flower of *Iris*, the style terminating in erect petaloid stigmatic lobes.
Fig. 261. Female flower of *Cucumis sativus*, with a short style and lobed stigma.
Fig. 262. Ovary of *Papaver*, with radiate sessile stigmas.

It has been stated that the styles of compound ovaries are often *distinct*; the stigmas are also often distinct on compound styles, indicating the

number of constituent carpels. Moreover these distinct stigmas are occasionally split down into two arms (*stigmata bicruria*), corresponding to the two placentas below: the one-celled ovary of Grasses and Compositæ (fig. 264) bears a two-armed stigma; and the stigmas of the compound ovaries of *Euphorbia* and some *Droseræ* are double the number of the carpels. Sometimes the distinct arms of different carpels cohere, and form stigmas equal in number to the placentas, but alternating with them.

Form and Position.—Stigmas, simple or compound, when distinct, are either *terminal* or *lateral*: in the latter case the stigmatic surface is on the ventral side. Their form is generally slender and thread-like, with a glandular stigmatic surface; but in the Grasses the stigmas are feathery (fig. 257) or *penicillate* (fig. 258); in the

Fig. 263.

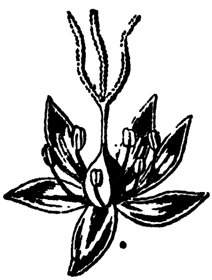


Fig. 264.

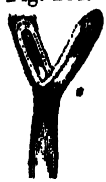


Fig. 265.

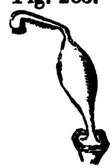


Fig. 266.

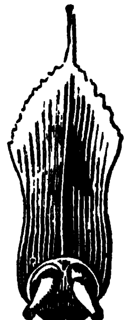


Fig. 267.

Fig. 263. Flower of *Luzula*, with one style and filiform stigmas.
Fig. 264. Linear stigmas of Composite plant, with papillose surfaces.
Fig. 265. Ovary of *Colutea*, with style and *lateral* stigma.
Fig. 266. Open carpel of *Pinus*, with two naked ovules at the base.
Fig. 267. Young female blossom of *Juniperus*, with the front carpel removed, showing the naked ovules.

Iridaceæ they are petaloid (fig. 259) or very much enlarged, as in *Iris* (fig. 260); and in other cases they are *capitate* (fig. 256), *lobed* (fig. 261), *peltate*, *radiate* (fig. 262), *filiform* (fig. 263), *linear* (fig. 264), &c. In Leguminosæ the stigmatic surface of the simple style is *lateral* (fig. 265).

The orifice of stigmas leading to the canal of the style is more or less filled by the glandular and capillary processes which clothe their surfaces; and, indeed, to the naked eye, the canal of the style does not appear permeable.

Gymnospermous Pistils.—The pistil of Gymnospermous plants consists of scales or *open carpels*, collected into *cones*, bearing exposed

ovules, so that no representative of the stylar or stigmatic regions exists here. Among the Coniferæ, *Pinus* and its allies have scale-like carpels with a pair of ovules on the upper surface, at the base (fig. 266); the structure is analogous, although the form of the scale differs, in *Thuja*; the Cypress has peltate scales, with numerous ovules; in *Juniperus* each of the three scales has only one (fig. 267). In *Taxus* the ovule is a solitary structure, a kind of free ovule, growing out from the apex of a small cone formed of barren scales. In the Cycadaceæ, *Cycas* has large leaf-like carpels, with numerous marginal ovules; *Zamia* has peltate scales, more like *Cupressus*, with the ovules pendent from the thickened summit.

By some authors what is above described as a naked ovule is thought to be an ovary (see under Gymnosperms).

Sect. 10. Products of the Essential Organs of Flowers.

Ovules.—Ovules are the rudiments of seeds, and arise from the placentas situated in the ovaries of Angiospermous plants (figs. 253–255), and on the margins or surface of the open carpels of Gymnospermia (figs. 266, 267). They originate as cellular papillæ at an early stage of development of the ovary, and acquire a definite form and structure by the time the flower expands.

Ovules are by some observers regarded, in part at least, as a kind of bud; for not only do they appear in the positions occupied by adventitious buds on vegetative leaves, as in *Bryophyllum*, but abnormal leaf-like carpels often bear bulb-like structures and foliaceous lobes, in place of the ovules, on their free margins. By others they are considered, at least so far as their outer coat is concerned, to be modified leaves or portions of such leaf. In most cases they originate from the margins or surface of a carpellary leaf; but in some cases they originate from the axis (free central placentation), and are then either lateral or terminal, as in Piperaceæ, where the end of the axis becomes the nucleus of the ovule. Other illustrations are afforded by *Taxus* and *Polygonum*.

Number.—The number of ovules in the ovary, or in one cell of a compound ovary, varies between wide limits. Thus the ovule is *solitary* in the simple ovaries of *Ranunculus*, *Prunus* (fig. 245), &c., in the compound ovaries of Polygonaceæ &c., and in each cell of the bilocular ovaries of the Umbelliferæ &c.; the number is still small and *definite* in the simple pistils of many Leguminosæ, in the cells of the compound ovary of *Quercus*, &c.; in a very large proportion of compound ovaries, whether unilocular or multilocular, the ovules are very numerous on each placental surface, and they are termed *indefinite*, as in *Primula*, *Papaver*, &c. &c.

Funiculus.—A fully developed ovule is usually attached to the placenta by a short stalk, called the *funiculus*, *podosperm*, or *umbilical cord*; where this stalk does not exist, the ovule is *sessile*; in a few cases the funiculus is very much elongated (Plumbaginaceæ).

Relative Position.—Special terms are used to indicate the position occupied by ovules in the ovary, and more particularly their direction. If the placenta is at the base of the ovary, and the ovule, springing from that situation, points upward, as in Polygonaceæ and Compositæ, the ovule is called *erect*; if it is attached at the summit, and hangs straight down, as in the Birch, Dipsaceæ, &c., it is *suspended*; when the placenta is central or parietal, the ovule may turn upwards and be *ascending*, may point straight outwards or inwards and be *horizontal*, or may turn downwards and be *pendulous*. In Plumbaginaceæ the ovule is suspended from the end of a long funiculus, which arises from the base of the ovary as in the erect condition.

Where numerous ovules exist on a central placenta, it is very common to find the upper ones ascending, the middle horizontal, and the lower pendulous, so that the direction becomes indefinite.

Parts of an Ovule.—The ovule arises from the placenta as a conical papilla, which soon becomes elongated into an oval body, the *nucleus*, raised on the stalk or *funiculus*. By the time the flower opens, the *nucleus* (figs. 268–270, *a*) generally becomes covered up by the *coats* or envelopes, which originate as circular ridges from the point where the funiculus is attached, and gradually grow up over the nucleus. The coats do not completely close in the ovule, but leave an opening at its summit, called the *micropyle* or *foramen* (figs. 268–270, *b*). The base of the nucleus, where the coats arise, is called the *chalaza*; the internal coat (the *secundine* of Mirbel) is the first formed; it is denominated the *integumentum internum*, or the *tegmen*; where only one coat exists, it is called the *integumentum simplex*. The outer coat, which grows up after the inner (the *primine* of Mirbel), is called the *integumentum externum*, or sometimes the *testa*. Sometimes, as in *Welwitschia*, the primine is prolonged beyond the apex of the ovule in the form of a tube greatly resembling a style (see under Gnetaceæ). The orifice named the *micropyle* forms a canal passing through both coats down to the point of the nucleus; and the portions passing through the outer and inner integuments are often called, respectively, the *exostome* and *endostome*. The point where the seed afterwards breaks away from the funiculus is marked by a scar, which is called the *hilum*.

In the Mistletoe the nucleus is naked, no coats being formed; in many cases there is only one coat; most ovules of Monocotyledons have two.

The coats of the ovule are usually regarded as foliar in their nature, the nucleus as axial—by others as a "trichome" or superficial emergence from the foliar coat of the ovule. The nucleus may be regarded as the equivalent of a macrosporangium among higher Cryptogams.

The above is a description of the ovule of what may be called the normal form, such as we find in *Polygonum*, &c.: where the nucleus is straight and the *micropyle* is at the end opposite the attachment of the *funiculus*, and the *chalaza* next the *placenta*, such an ovule is called *straight*, or, more technically, *atropous* or *orthotropous* (fig. 268).

Inversion and Curvation of the Ovules.—Very frequently the *funiculus* grows in a state of confluence with the outer integument, during the development of the ovule, so as to push up the base of the nucleus until it is completely inverted (fig. 269), and

Fig. 268.

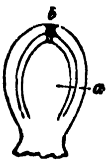


Fig. 269.

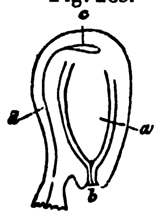
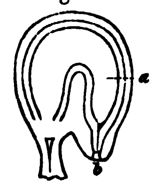


Fig. 270.



Diagrammatic vertical sections of ovules: *a*, the nucleus; *b*, the micropyle; *c*, chalaza; *d*, raphe.

Fig. 268. An atropous or orthotropous ovule.
Fig. 269. An anatropous ovule. Fig. 270. A campylotropous ovule.

the micropyle (*b*) points to the placenta, while the chalaza (*c*) is at the opposite end, the nucleus being straight as in orthotropous ovules: this is the *inverted* or *anatropous* condition (Compositæ, Liliaceæ, &c.); and as the funiculus is confluent with the outer coat, the *hilum* (the external point of junction of the *funiculus* with the body of the ovule) is left in its original position, and therefore close beside the inverted micropyle. The adherent portion of the funiculus often forms a kind of ridge extending from the hilum to the chalaza: this is termed the *raphe* (fig. 269, *d*). Other ovules become anatropous not by reflexion, but by unequal growth.

The inverted ovule is a straight ovule with a long funiculus confluent with the outer coat: in *Fumana* (Cistaceæ) the real condition often actually illustrates this; and in seeds formed from anatropous ovules the raphe sometimes separates (*Zygophyllum*, *Willdenovia*).

The position of the raphe with reference to the ovule varies in different cases; sometimes it is *ventral*, or on the side of the ovule nearest to the placenta, sometimes *dorsal*, at other times *lateral*.

A curved or *campylotropous* ovule (fig. 270) is formed by the

bending over of the nucleus upon itself in the form of the letter U, carrying the *micropyle* (*b*) over, but leaving the *chalaza* in its natural vicinity to the hilum.. There is no raphe in such ovules.

Another condition more rarely met with is the horizontal or *amphitropous* ovule, intermediate between straight and inverted, the adherent funiculus pushing up the chalaza at one end, while the micropyle descends in a corresponding degree, until the axis of the ovule becomes horizontal, and parallel with instead of at right angles to the placenta.

In the first instance all ovules are straight, but they mostly become curved during the course of their development.

The Embryo-sac.—At the time when the flower expands, there exists a more or less considerable sac or cavity excavated in the substance of the nucleus, the upper end of which sac is situated just within the apex. This cavity is called the *embryo-sac*, being really a sac or bag with a proper wall, within which the *embryo* or rudiment of the future plant is developed after fecundation. It is analogous to the *macrospore* of Cryptogamous plants.

The phenomena of fecundation and of the early development of the embryo, together with the minutiæ of the anatomy of ovules, are reserved for the Physiological part of this work.

The further morphological peculiarities of the ovular structures will fall best under the head of the *seed* or completed product, previously to examining which we must follow out the ultimate history of the pistils and associated organs forming the *fruit*, in which the ripe seeds are found.

The Fruit.—The fertilization of the ovules usually takes place soon after the opening of the flowers, or sometimes even before their expansion. During the subsequent changes by which the ovules are converted into seeds, the ovary (and occasionally other parts of the flower) undergoes further development, and becomes what is technically called the *fruit* or seed-vessel.

Changes during the ripening of the Fruit.—Generally the stamens and corolla, and not unfrequently the calyx also, fall away or wither up after fertilization, and the styles, with the stigmas, mostly disappear; but the style sometimes persists, and even undergoes enlargement, forming a kind of *beak* or *tail* to the fruit, especially in simple fruits formed of one carpel (*Ranunculus*, *Clematis*, *Geum*, fig. 289, &c.). The calyx, when *inferior*, remains in many cases as a loose cup or envelope surrounding the fruit (as in Labiatæ, many Solanaceæ, fig. 184, &c.); or, when *superior*, its segments, enlarged or withered, form a kind of crown to the fruit (Compositæ, Campanulaceæ, &c., fig. 283), and the tubes of adherent calyces always enter into the composition of the inferior fruits (figs. 298–303). In some cases the calyx and the corolla, in other cases the receptacle,

become blended with the ovary or ovaries to form the fruit; and a still more complex kind of fruit is formed by all the flowers of an inflorescence becoming conjoined into a common structure during the ripening of the seed, so as to form a collective fruit, such as occurs in the Pineapple (fig. 308), Mulberry (fig. 307), Bread-fruit, the Fig (fig. 306), cones of Firs, &c.

Considered as developments of the carpels alone, many fruits in their mature condition depart widely in appearance from the ovaries from which they are produced, the morphology of fruits exhibiting perhaps more remarkable cases of actual metamorphosis than any other parts of plants. Hence it is often difficult to judge from a fruit what kind of pistil the flower has possessed, and the structure of fruits can only be understood by a study of their progressive development from the immature to the mature condition.

The most important source of change is the *suppression* of chambers or loculi of the ovary, together with the abortion of ovules. Thus the flower of the Birch has a two-celled ovary with one ovule in each cell; but one cell with its ovule is constantly abortive and almost entirely disappears in

Fig. 271.

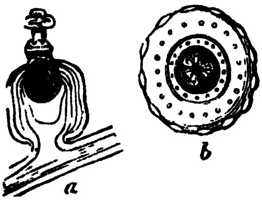


Fig. 272.

Fig. 271. Female flower of the Oak: *a*, vertical section; *b*, cross section.
Fig. 272. Fruit of the Lime (*Tilia*): *a*, entire; *b*, cross section.

the fruit. In the female flower of the Oak and hazel-nut there are three cells, each with two ovules (fig. 271); but only one cell is found in the ripe fruit, and this is filled by one solitary remaining seed, as we find in the Acorn or nut. In the Lime there are several cells in the ovary, but generally all but one are obliterated in the fruit (fig. 272); and similar cases are by no means uncommon. In these cases the dissepiments, called in the fruit *septa*, are not broken down, but pushed to one side and obliterated by the pressure exercised by the developed seed.

On the other hand *spurious partitions* are sometimes formed, as in *Datura Stramonium*, which has a four-celled fruit derived from a two-celled ovary: and in the pods of Leguminosæ cross partitions are often produced between the seeds.

The original conditions are frequently still further concealed by the alterations in the texture of the coverings of the fruit, next to be described.

The Pericarp.—The "wall" of the fruit is the substance formed from the carpels, or (when present) from the other component

structures. It constitutes the case enclosing the ripe seed or seeds, and is called the *pericarp*. The pericarp is of very different structure in different fruits. When the fruit is mature, it may be *dry*, *membranous*, *leathery* (*coriaceous*), *woody*, or *succulent*; or it may be succulent externally and woody within, or succulent internally and woody or leathery outside.

The ripe pods of common Peas afford examples of a dry membranous pericarp; the Flags (*Iris*) have a *leathery* pericarp; the common Hazel-nut &c. have a *woody* pericarp. The pericarps of the Grape and the Gooseberry are *succulent* or *baccate*. The Plum, Cherry, &c. are succulent externally and woody within (*drupaceous*); the Orange, the Pomegranate, the Pumpkin, &c. are succulent within and leathery or horny outside.

When the *pericarp* is uniformly membranous or woody, without distinction of layers, no subdivisional terms are applied to it. The same holds good in respect to the simple *succulent pericarp* of such fruits as the Grape and Gooseberry. When there is a distinction into layers, formed by a gradual alteration of the texture of the inner and outer parts during maturation, we distinguish between an *epicarp* and an *endocarp* or *pyrene*—as, for example, in the Plum, Cherry, Walnut, &c., where there is a succulent *epicarp*, and a woody *endocarp* forming the "stone;" the "core" of the Apple is a membranous endocarp. When a fruit, such as the Orange, Pomegranate, Litchi, &c., is firm externally, with a leathery or woody *epicarp* and a succulent *endocarp*, the latter is generally derived from development from the placental regions. In common "stone-fruits" the two regions are often distinguished by the names *sarcocarp* (or pulp) and *putamen* or *pyrene*. In the Date-Palm (fig. 280) the "stone" consists of the albuminous seed, which is invested by a succulent pericarp. In other Palms, such as *Areca*, the pericarp is fibrous. In hard-rinded succulent fruits we have an internal *sarcocarp* enclosed by a *cortex* or rind.

Many authors, following De Candolle, divide the pericarp into *epicarp*, *mesocarp*, and *endocarp*. It may be observed here that the distinction between endocarp and epicarp, in the common stone-fruits, arises entirely during the ripening of the fruit; the two regions are originally alike and undistinguishable; it is well known that the easy separation of the pulp from the stone is a sign of ripeness.

Dehiscence of Fruit.—Some fruits, more particularly the succulent kinds, but also many dry fruits, do not burst to discharge their seed or seeds when ripe; these are called *indehiscent fruits*. The pericarp rots away, or is broken irregularly or perforated when the seed germinates. Most dry fruits, more particularly those formed of more than one carpel, burst open or separate into pieces in a regular manner when mature, and are consequently *dehiscent*.

Dehiscence takes place generally (1) by the separation or splitting of the sutures of the carpels in a vertical direction, or (2) by the dissociation of coherent carpels, or (3) by both together. The parts which

separate in the first way are called *valves*; and this mode of bursting is termed *sutural* or *valvular dehiscence*. The separated carpels in the second mode are called *cocci* if they do not open as explained in a subsequent paragraph. Sometimes the valves only separate for a certain distance from the summit, forming teeth (fig. 273). In a few cases the dehiscence is *porous*; in others the upper end of the fruit falls off like a lid, by *transverse* or *circumscissile dehiscence* (fig. 274).

Fig. 273.

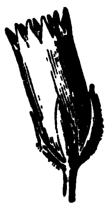


Fig. 274.

Fig. 275.

Fig. 273. Burst capsule of *Cerastium*.
Fig. 274. Capsule of *Anagallis* (sometimes called a pyxis), opening by circumscissile dehiscence.
Fig. 275. Burst fruit of *Illicium* (Star Anise).

Valvular Dehiscence.—When the dehiscence is *valvular* the fruit is named bi-, tri-, multivalvular according to the number of valves or pieces into which it splits. This mode of dehiscence is subject to several modifications, according as the splitting takes place through the dorsal or through the ventral suture, or through both at the same time. It is still further complicated by the circumstance that the placentas sometimes remain attached to the valves, while at other times they break away from the valves, as in the condition called *septifragal*.

A few examples may be here given of the various modes in which valvular dehiscence is effected; and the student will find the subject far more readily intelligible if he refer to some collection of seed-vessels where the fruits are correctly named. In the case of *simple* or of *apocarpous* fruits, there is no partition or dissepiment, the cavity being simple; in such cases valvular dehiscence takes place:—*a*, through the ventral suture, as in the Columbine (*Aquilegia*), the Star Anise (*Illicium*, fig. 275); or, *β*, through the dorsal suture, as in *Magnolia*; or, *γ*, through both sutures at the same time, as in the pod of the Pea and other Leguminous plants (fig. 286). In this latter case there are two valves, but only a single carpel.

In *unilocular syncarpous* fruits, where the compound carpels cohere by their edges which are not infolded, dehiscence takes place:—*a*, through the ventral sutures, when the placentas are found on the margins of the valves, as in Gentians (fig. 253), each valve in this case representing a carpel; *β*,

through the dorsal sutures, when the placentas will be found in the middle of the valves, as in the Violet (fig. 254). In such fruits each valve consists of two half-carpels combined. In the Orchidaceæ the capsules dehisce in the manner last described, with this further peculiarity—that the valves, bearing the placentas in the middle, separate from the midribs or dorsal sutures, leaving these latter attached together at the top, and thus forming an open framework supporting the remains of the perianth.

In *multilocular syncarpous* fruits, where the sides and margins of the component carpels are infolded, so as to form partitions or dissepiments, the dehiscence is likewise through the dorsal, or ventral, or through both sutures; thus dehiscence takes place:—*a*, *loculicidally*, through the dorsal sutures, so as to open the loculus or cavity of the carpel from behind; each valve in this case represents two half-carpels (figs. 277, 278); or, *β*, *septicidally*, through the septa, so as to isolate the previously combined carpels (fig. 276). Each segment in this case represents an entire carpel.

Fig. 276.

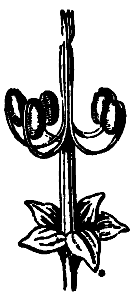


Fig. 277.

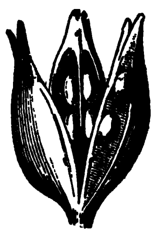


Fig. 278.

Fig. 276. Ripe fruit of *Geranium*, the tailed *cocci* separating elastically from the carpophore.
Fig. 277. Burst capsule of *Iris*, with loculicidal dehiscence.
Fig. 278. The same in cross section.

Septicidal and loculicidal dehiscence may occur in the same fruit, as in the Foxglove (*Digitalis*), the capsule of which first divides into its constituent carpels septicidally, and afterwards each carpel splits loculicidally into two valves; the four valves so produced represent each a half-carpel.

Both the loculicidal and septicidal modes of dehiscence are sometimes associated with what is termed *septifragal* dehiscence. This occurs when the *septa* or partitions bearing the placentas are broken across; the effect of this is that the valves break away from the placentas, leaving part or the whole of the latter standing in the centre of the fruit on a kind of column, as in *Andromeda*, *Convolvulus*, *Rhododendron*, &c. *Septifragal dehiscence* takes place by itself in the *siliques* or pods of Cruciferæ, where the valves separate from the parietal placentas, leaving them in the centre supporting the ovules (figs. 295 & 296).

Schizocarps.—In some instances, as in *Galium*, the carpels separate one from the other without opening. In such a case the term *schizocarp* is employed to designate the whole fruit, while its component carpels are

called *cocci*, or where there are two, as in Umbellifers, *mericarps* (fig. 300). More frequently the carpels not only separate septicidally but each one bursts, through the dorsal suture, as in *Geranium* (fig. 276), or through the ventral suture, as in *Colchicum*.

Dehiscence by teeth only differs from that by valves in the smaller degree of separation. The fruits or seed-vessels of Caryophyllaceæ dehisce by teeth. Sometimes the teeth are equal in number to the carpels, as when the dehiscence is through the ventral sutures only (*Lychnis*); sometimes double the number of the carpels, when the splitting takes place through both sutures (*Dianthus*) (fig. 273).

Porous Dehiscence arises from the formation of orifices in the walls of a dry capsule, allowing the seeds to escape. In the Poppy (*Papaver*) a circle of *pores* is formed round the upper edge of the fruit, just beneath the stigma; in *Antirrhinum* and *Linaria* there are two or three orifices near the summit of the capsule; in some Campanulas a pore is formed at the base of each cell.

In all these cases the orifices are formed from thin spots in the walls, which tear open, their edges curling back in more or less regular teeth: the dehiscence of *Antirrhinum* is connected by that of *Scrophularia*, *Digitalis*, &c. with the dehiscence into a crown of teeth as in *Primula* and Caryophyllaceæ.

Transverse or **Circumscissile Dehiscence**, observed in the membranous capsules of *Hyoscyamus* (fig. 294), *Anagallis* (fig. 274), *Plantago*, &c., and in the woody fruits of *Lecythis*, arises from a transverse fissure running round the wall and splitting off the upper part of the fruit like a lid. A dehiscence analogous to this occurs in the *lomenta* of various Leguminosæ, which break across in several places between the seeds.

In these cases a kind of articulation is produced, by the tissue of the pericarp remaining more delicate in the line of dehiscence, so that it becomes torn by the hygrometric contraction or expansion of the firmer parts above and below, after the fruit has become mature.

Period of Dehiscence.—Dehiscence does not usually take place until the seeds are ripe; but in Mignonette (*Reseda*) the ovary opens before; in *Leontice thalictroides* the ovary bursts very early, and the seed ripens in a naked condition. In *Impatiens* and some other plants dehiscence takes place suddenly with considerable force, the valves separating and rapidly curling up. In *Elaterium* the peduncle separates in a similar sudden way from the ripe fruit, and the seeds are forcibly ejected.

Fruit of Gymnosperms.—In Gymnosperms there is of course no proper dehiscence; but in most cases the carpellary scales of the female cones, which are separate to some extent during fertilization, frequently close up together so as to form an apparently solid body while the seeds are ripening, as in *Pinus*, *Cupressus*, *Thuja*, &c. (fig. 309). The scales open again when the seeds are ripe,

but in some cases not for many years, and in other cases they separate from the axis. In *Juniperus* the scales become succulent. In *Taxus* the solitary ovule is naked; but during the ripening of the seed a succulent cup-like envelope grows up round it.

Forms of Fruit.—The forms of perfect fruit are distinguished by technical names, and in defining them it is desirable to classify them in some way. The classification which conveys the greatest amount of information is that founded primarily on the construction of fruits.

Fruits may be divided first into *free* or *monothalamic fruits*, formed from single flowers, and *confluent fruits*, formed of the blended flowers of an inflorescence. The term *polythalamic* has been conveniently applied to fruits of this latter kind.

Free fruits may be divided into:—1. *Apocarpous fruits*, where the constituent carpels are solitary, or, if more than one, separate; 2. *Syncarpous fruits*, formed of compound ovaries, and consisting of (*a*) *superior fruits* when the calyx is free, and (*b*) *inferior fruits* when the tube of the receptacle or of the calyx is adherent.

Confluent fruits require no corresponding subdivision.

The following are the terms most usually employed, and very many more might be enumerated; but botanists now content themselves with a few well-defined types, and for the rest use such terms as capsular, baccate, &c., to indicate the general nature of the fruit, as more rigidly applied terms are not only cumbersome, but often fail in practice.

Apocarpous Fruits.

Achænium.—The *Achænium* is a small, dry, indehiscent, one-seeded pericarp, tipped with the remains of the style, and with the seed free in the interior, except at the point of attachment.

This fruit is rarely found solitary, as in *Alchemilla*; it usually forms

Fig. 279.

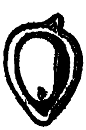


Fig. 280.

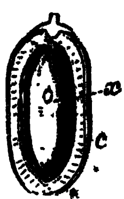


Fig. 281.

Fig. 282.

Fig. 279. Achænium of *Ranunculus* cut vertically to show the seed.
Fig. 280. Section of the fruit of the Date (*Phœnix dactylifera*): *c*, the pericarp; *x*, the embryo imbedded in the horny albumen.
Fig. 281. Circles of follicles of *Sempervivum*.
Fig. 282. Persistent calyx of a Boraginaceous plant, opened to show the carcerulus formed of four indehiscent carpels, separating from each other.

part of a multiple fruit, as in *Ranunculus*, *Geum* (fig. 289), &c., where they occur on a dry receptacle or thalamus, or as in the Strawberry, where they occur imbedded in a succulent receptacle. Achænia are popularly mistaken for seeds, from which they may be known by the stylar beak and by the seed lying loose inside.

The term achænium is often loosely applied to the halves of Umbelliferous fruits (fig. 300), the cocci of Mallows, the *nucules* or *nuts* of Boraginaceæ, Labiatæ, &c. (the *carcerule* of some authors) (fig. 282), and to the *cypselæ* of Compositæ (figs. 283-285).

Fig. 283.

Fig. 284.

Fig. 285.

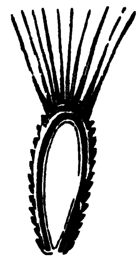


Fig. 283. Cypsela of *Scorzonera* Fig. 284. Cypsela of *Bidens*
Fig. 285. Cypsela sliced vertically, to show the seed within.

Drupe.—The *Drupe* is a one-celled fleshy fruit, represented by stone-fruits formed from a single pistil, such as the Cherry or Plum, where the stone is formed by the inner part of the pericarp, and the pulp by the outer part.

In common stone-fruits the drupe is solitary; but minute drupes formed on the same plan are assembled together on the receptacle of the Raspberry and Blackberry (fig. 290). The term drupe is often improperly applied to the compound stone-fruits, like the Cocoa-nut, &c.,—or to the Date, where the stone is formed by the seed alone, and the pulp by the pericarp (fig. 280). Fruits of this general kind are called drupaceous.

Follicle.—The *Follicle* is a simple pod, splitting down the ventral suture only, and bearing the numerous ovules on its margins.

This rarely occurs solitary, but mostly combined with others in a circle, as in *Aquilegia*, *Sempervivum* (fig. 281), &c.; and they are then often coherent at the base.

Legume.—The *Legume* is a one- or many-seeded simple fruit, usually splitting down both sutures, with the placentas on the margins of the ventral suture.

In most cases the *legume* is elongated and pod-like (fig. 286), as in the Pea, &c.; but sometimes it is curved or even spirally coiled like a snail's shell, as in *Medicago* (fig. 287), or lobed and knotted, as in *Acacia* (fig. 288). In *Astragalus* a spurious sutural septum is formed by projection inward of one of the sutures (fig. 252).

The *Lomentum* is a modification of the legume, either wholly indehiscent, or constricted into joints between the seeds and sometimes falling

Fig. 286.

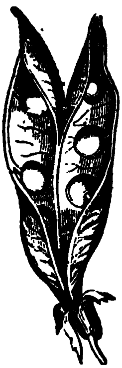


Fig. 287.

Fig. 288.

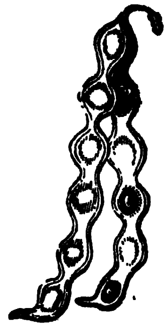


Fig. 286. Legume of Pea, burst.
Fig. 287. *a*, Curled legume of *Medicago sativa*; *b*, of *Medicago orbicularis*.
Fig. 288. Legume of an *Acacia*.

to pieces in these situations, as in *Ornithopus*, *Desmodium*, &c. In the lomentum of *Cassia* (e. g. *Cassia Fistula*) there are many false cross septa.

Fig. 289.

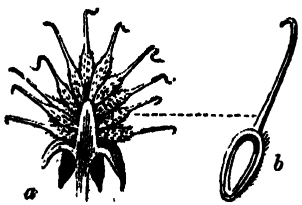


Fig. 290.

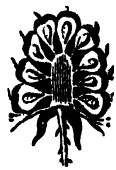


Fig. 289. Multiple fruit of *Geum*, cut vertically (*a*) to show the attachment of the component achænia (*b*) on a dry receptacle.
Fig. 290. Multiple fruit of Blackberry (*Rubus*), cut vertically, showing the spongy receptacle covered with little drupes.

Syncarpous Fruits—Superior.

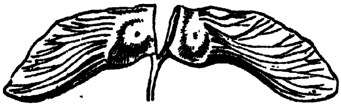
Caryopsis.—The *Caryopsis* is the one-seeded fruit of the Grasses, composed of two or, rarely, three carpels, which form a dry pericarp inseparable from the seed. In practice it is hardly recognizable from the achene, except in the last-mentioned characteristic.

Samara.—The *Samara* is a two- or more-celled, few-seeded, dry, indehiscent fruit, which has a membranous wing or wings

Fig. 292.

Fig. 291.

Fig. 293.



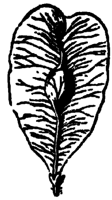


Fig. 291. Double samara of the Maple (*Acer*).
Fig. 292. Samara of the Elm (*Ulmus campestris*).
Fig. 293. Samaroid fruit of the Birch (*Betula alba*).

developed from the pericarp—as in *Acer* (fig. 291), *Ulmus* (fig. 292), and the little fruits of the catkin of the Birch (fig. 293). Practically this may be regarded as one or more achenes with winged pericarps.

Pyxis.—The *Pyxis* is a one- or more-celled, many-seeded fruit, the upper part of which falls off like a lid by circumscissile dehiscence, as in *Anagallis* (fig. 274), *Hyoscyamus* (fig. 294), *Lecythis*, &c. It differs from the capsule merely in its transverse dehiscence.

Silique.—This is a two-valved linear pod, the valves of which separate septifragally from a kind of frame, with a more or less perfect false septum (*replum*) stretched across it, the parietal placentas being attached to the frame, as in *Sinapis* (fig. 295), *Cheiranthus*, &c. It is the characteristic fruit of Crucifers.

The *Silicula* (diminutive of the last) is merely a short and broad siliqua, often most expanded in the direction at right angles to the *replum*, the valves sometimes winged—*Thlaspi* (fig. 296), *Capsella*, &c.

When the *replum* is imperfect, it is said to be *fenestrate*; or it may be destroyed altogether. Some siliques and siliculas do not burst by valves —*Crambe, Raphanus, Isatis* (fig. 297), &c.

Capsule.—The *Capsule* includes all the remaining kinds of dry fruits, membranous or woody, formed of one-celled or many-celled compound ovaries, which dehisce more or less completely by regular valves, equal in number to or double that of the carpels (*Iris*, *Colchicum*, Caryophyllaceæ, *Digitalis*, *Primula*, &c.), or by pores (*Antirrhinum*, *Papaver*). Its mode of dehiscence may be septicidal,

loculicidal, or septifragal. Fruits of this general character are called capsular.

Fig. 294.

Fig. 296.

Fig. 295.

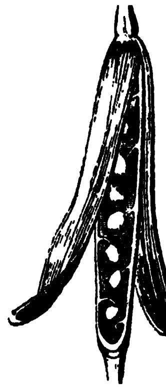


Fig. 297.

Fig. 294. Pyxis of *Hyoscyamus*, enclosed in the dry calyx.
Fig. 295. Burst siliqua of *Sinapis*, the valves separating from the sutures supporting the replum.
Fig. 296. Burst silicle of *Thlaspi*.
Fig. 297. Indehiscent fruit of *Isatis*: *a*, entire; *b*, a cross section.

Syncarpous Fruits—Inferior.

Glans.—The *Glans* is a hard, dry, indehiscent fruit, spuriously one-celled from suppression, usually one-seeded, seated in a persistent involucre forming a *cupule*. In the Acorn and Hazelnut there is a single gland in each cupule or cup, while in the Beech and Chestnut there are several.

The ovary of the Oak is 3-celled, with two ovules in each cell; but two cells with their ovules, together with one ovule of the fertile cell, are suppressed, and the wall of the ovary (fig. 271) is converted into a bony shell, completely filled by the remaining seed. The ovary of the Birch is also 3-celled, that of the Hazel 2-celled, that of the Chestnut 3–8-celled; and similar suppression takes place. The inferior character of the fruit is marked, especially in the Chestnut, by the remains of the teeth of the calyx on the summit (fig. 216, p. 117). In the Acorn the gland is naked above, seated in a cup; in the Hazel the leafy cupule envelopes it; and in the Chestnut and Beech the spiny cupule encloses several fruits.

Cremocarp.—The *Cremocarp* is a schizocarpous or splitting fruit, consisting of two inferior achenes formed from a two- or

several-celled compound inferior ovary, the cells of which separate when ripe as indehiscent *cocci*. The separate halves of the two-celled fruit of Umbelliferæ are frequently called *mericarps* (figs. 298–300) (*Galium* and many other Rubiaceæ, &c.).

Fig. 298.

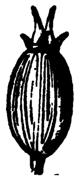


Fig. 299.

Fig. 300.

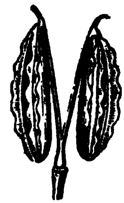


Fig. 298. Fruit of *Œnanthe*, the halves not separated.
Fig. 299. Cross section of the fruit of the Carrot.
Fig. 300. Fruit of Umbelliferæ, the mericarps separated and hanging from the carpophore.

Bacca, or **Berry.**—The *Bacca*, or true berry, is an inferior succulent fruit, crowned by the withered teeth of the calyx; it is uniformly pulpy, with a thin skin, the numerous seeds being imbedded in the pulp—Gooseberry, Currant, Cornel (fig. 302), &c. The term "*baccate*" is now generally applied to all succulent fruits, whether superior or inferior, which have not a distinct stone like a drupe, as fig. 301.

Fig. 303.

Fig. 301.

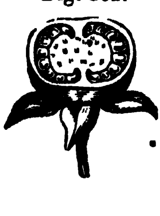


Fig. 302.

Fig. 304.

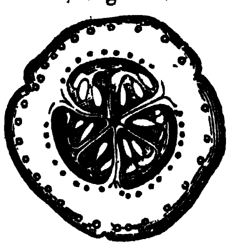
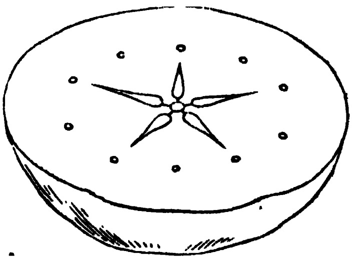


Fig. 301. Nuculanium, uva, or superior berry of *Solanum*, cut across.
Fig. 302. Berry of Cornel (*Cornus mas*).
Fig. 303. Vertical section of the pome of *Mespilus* (Medlar).
Fig. 304. Cross section of the pepo of Cucumber.

Pome.—The *Pomum* (fig. 305) is a compound, many-celled succulent fruit, in which the epicarp is fleshy, while the endocarp forms either cartilaginous linings and partitions to the cells (a "core"), or bony shells around the more or less separated cells—Apple, Quince, Medlar (fig. 303), Hawthorn, &c. The fleshy portion of the pome consists of a dilatation of the upper end of the flower-stalk, in which the true carpels are imbedded.

Fig. 305.



Pome of Apple.

Pepo.—The Gourd is a succulent inferior one-celled fruit, with the seeds on three parietal placentas, imbedded in pulp, which often fills up the cavity; the epicarp is more or less leathery (Cucumber, fig. 304), or thickened and indurated (Gourd).

Infrutescences or Confluent Fruits.

Syconus.—The *Syconus* is a succulent fruit, formed of an enlarged fleshy excavated or concave flowering axis, in which are imbedded numerous separate fruits with dry pericarps. In the Fig the seed-like pericarps are seated on the walls of the internal cavity (fig. 306); in *Dorstenia* they are imbedded in the concave-topped common receptacle.

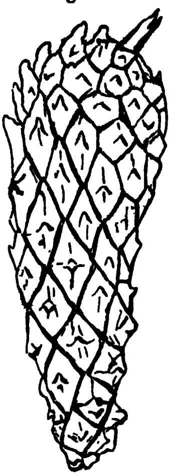
Fig. 306.

Fig. 307.

Fig. 308.

Fig. 306. Vertical section of the Fig (*Ficus Carica*).
Fig. 307. Fruit of Mulberry (*Morus nigra*).
Fig. 308. Fruit of Pine-apple (*Ananassa sativa*).

Fig. 309.



Sorosis.—The *Sorosis* differs from the foregoing by the substance of the constituent pericarps, formed of the ovaries and floral envelopes of the flowers, becoming pulpy and confluent with each other (*Morus*, fig. 307), and sometimes with the succulent axis of the inflorescence (Pine-apple, fig. 308, Bread-fruit).

Strobilus.—The *Strobilus*, or Cone, is the characteristic fruit of the Gymnosperms, consisting mostly of a conical or ovate mass of imbricated scales, with seeds in their axils (or on their borders, *Cycas*), each scale being the development of a single carpel, representing a female flower (*Pinus*, fig. 309).

The *Galbulus* is a kind of cone with few scales, which have their heads thickened and forming the periphery of a somewhat globular mass, dry (*Cupressus*), or sometimes succulent (*Juniperus*, fig. 267).

The Seed.

Formation of the Seed.—The consequence of the fecundation of the ovule is the development of an *embryo* in the embryo-sac (p. 139); and during the maturation of the fruit the ovules are perfected into *seeds*, the essential character of which is, that they are independent reproductive bodies, containing an *embryo* or rudimentary plant at the time when they are cast off by the parent (fig. 311 B, *e*).

Fig. 310.

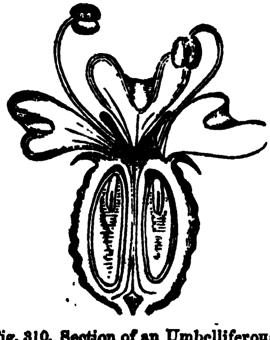


Fig. 311.

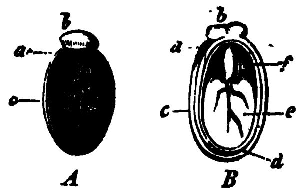


Fig. 310. Section of an Umbelliferous flower, showing the two seeds *in situ*, each containing an embryo at the upper end, imbedded in albumen.

Fig 311. Seed of Castor-oil plant (*Ricinus*): *A*, external view; *B*, vertical section: *a*, *hilum*; *b*, *micropyle*, with an *arillode* around it; *c*, *raphe*, leading to (*d*) the *chalaza*; *e*, *embryo*, with foliaceous *cotyledons*, and *radicle* pointing to the *micropyle*; *f*, *perisperm* or *albumen*.

The seed remains attached to the placenta of the fruit, until mature, by the *funiculus*, from which it ultimately separates by an articulation, so that a scar is left, called the *hilum*.

The *direction* and position of the seeds in the cells of the fruit, as well as the modes of curvature, indicated externally by the relative positions of the hilum (fig. 311, *a*), micropyle (*b*), chalaza (*d*), and raphe (*c*), are the same as in the case of the ovule; and the same terms are made use of in describing their peculiarities.

The face of a seed is the side or edge turned towards the placenta from which it arises.

The direction of seeds may differ from that of the ovules, by alteration in the shape of the ovary, abortion of ovules, &c. It may be noted that anatropous ovules normally have the raphe *next* the placenta if *ascending* or *suspended*, so that the raphe indicates the face.

Parts of the Seed.—The seed consists of the proper *body* of the seed and its integuments, to which in some cases are added appendages of various kinds.

The outer coat of the seed, called the *testa*, completely encloses it, marked, however, by the microscopic orifice of the *micropyle*, and by the *hilum*, or scar of the funiculus. The testa presents the greatest possible variety of conditions of texture, from membranous, horny, woody, or bony hardness, on the one hand, to a leathery or soft, pulpy condition on the other. The dry forms frequently exhibit beautifully regular markings, such as minute ridges, reticulations (Poppy, *Silene*, &c.), spines (*Stellaria*, &c.); or the margins are produced into sharp edges or broad wings (*Bignonia*, *Pinus*, fig. 312); or it bears a crown of hairs, or *coma*, at one end, as in *Epilobium*, *Asclepias*, &c.; or it is completely covered with long hairs, as in the Cotton plant: while in various Polemoniaceæ, Labiatæ, &c. (*Collomia* &c.) it is clothed with microscopic hairs, which expand elastically and dissolve into a kind of mucilage when wetted. Sometimes the testa is loose, and forms a kind of sac around the body of the seed, as in Orchidaceæ, *Pyrola*, &c.

Fig. 312.

Winged seed of Pine.

The *inner integument*, the *tegmen* or *endopleura*, is not generally distinguishable; when it is, it is usually whitish and delicate.

The reference of the integuments of the seed to their elements in the ovule is a subject of great complexity, since there appear to be no rules as to what regions of the ovule, from the nucleus outward, shall remain distinguishable or enter into the composition of the coats. The testa is commonly formed of the *primine* and *secundine* (p. 137) of the ovule conjoined. The tegmen seems to originate sometimes from the secundine, sometimes from the substance of the nucleus, &c. Small indehiscent fruits, such as the achænia of *Ranunculus* (fig. 313) or of Borages (fig. 282, p. 145),

are liable to be mistaken for seeds when detached; they are known by the remains of the style, and by the complete seed with its proper coat being distinguishable on opening the pericarp (fig. 313).

Fig. 313.

Fig. 314.

Fig. 315.

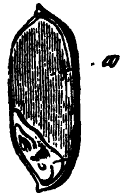


Fig. 316.

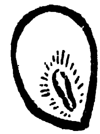


Fig. 313. Vertical section of an achænium of *Ranunculus*, showing the seed within the pericarp and with a minute embryo in the albumen.
Fig. 314. Section of the seed of *Typha*, showing the straight embryo in the axis of the perisperm or albumen.
Fig. 315. Section of the caryopsis of Wheat, showing the abundant perisperm, *a*, with the embryo, *b*, at the base, outside.
Fig. 316. Section of the seed of *Iris*, with the embryo enclosed in the perisperm.

Enations from the Seed.—A considerable number of seeds possess a coat or appendage distinct from the proper integument, and produced *entirely during the development of the seed from the ovule*—that is to say, after the fertilization of the latter. These additional structures are frequently fleshy when mature, as in the Spindle-tree, *Euonymus*, *Podophyllum*, &c. The older authors called all the forms by the same term, *arillus*; recent authors distinguish the *true arillus*, which grows up over the seed from the funiculus, like the primine and secundine, as in *Nymphæa*, Passion-flowers, &c., from the *arillode*, which originates at or near the micropyle, and grows down more or less over the testa, as in *Euonymus* (where it forms a pulpy coat), in *Euphorbia*, *Ricinus* (fig. 311), *Polygala*, &c.

The *mace* of the nutmeg is an arillus, adhering both to the hilum and micropyle.

The appendages which grow from the raphe, in *Chelidonium*, *Asarum*, *Viola*, &c., are sometimes called *strophioles*.

The body of the seed is composed either of the *embryo* alone, or of the embryo imbedded in a mass of tissue, called the *perisperm*, or *albumen* (figs. 313–320). Seeds wherein the embryo is immediately invested by the integuments are commonly called *exalbuminous* or *aperispermic* (figs. 321 & 323). Where *perisperm* exists, they are called *albuminous* (figs. 313 &c.).

The term *albumen*, founded upon the functional analogy with the albumen or white of an egg, is very inconvenient, as it has a distinct chemical sense, in which it is frequently used in the chemical questions of vegetable

; and therefore the word *perisperm* is preferable. All seeds in their rudimentary condition contain perisperm; but as the embryo grows it is often absorbed, so that in the ripe seed it is no longer perceptible. It is considered to be analogous with the prothallus of the higher Cryptogams.

The Perisperm varies very much in both quantity and in texture —in proportion to the relative magnitude attained by the embryo (figs. 313 & 320), and in consequence of the different mode of

Fig. 317.

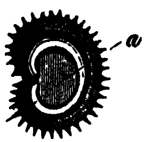


Fig. 318.

Fig. 319.

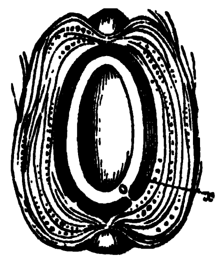


Fig. 317. Section of the seed of *Lychnis*, with a peripherically curved embryo, *b*, surrounding the perisperm, *a*.
Fig. 318. Section of the seed of *Piper*, showing the embryo in a separate sac at the apex of the perisperm, which latter is hollow in the middle.
Fig. 319. Section of the fruit of the Cocoa-nut Palm, showing the fibrous epicarp, the woody endocarp (*x*) enclosing the hollow perisperm, in which lies the minute embryo.

development of the cellular tissue and its contents in different cases.

The texture or consistence of the perisperm is termed *mealy* or *farinaceous* when it may be readily broken down into a starchy

Fig. 320.

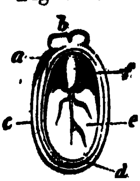


Fig. 321.

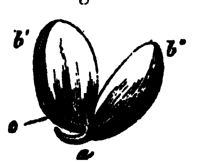


Fig. 322.

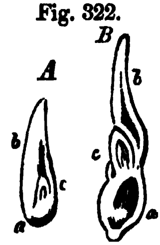


Fig. 320. Vertical section of the seed of *Ricinus*: *a*, hilum; *b*, micropyle; *c*, raphe; *d*, chalaza *e*, embryo; *f*, perisperm.
Fig. 321. Aperispermic dicotyledonous seed of a Bean, with the coats removed: *a*, radicle; *b'*, *b''*, cotyledons (separated to show the plumule, *c*).
Fig. 322. Monocotyledonous embryos removed from the perisperm, vertically sliced: A, of *Calla palustris*; B, *Avena* (Oat): *a*, radicle; *b*, cotyledon; *c*, plumule.

powder (as in Corn-grains &c.); *oily* when it is composed of soft

tissue loaded with fixed oil (as in the Poppy and Cocoa-nut); *mucilaginous* or fleshy when it is tougher and swells up readily when wetted (as in the Mallow); *horny* when hard and more or less elastic (as in Coffee, *Galium*, *Iris*, &c.).

The perisperm is usually a uniform mass; but in *Nymphæa*, Piperaceæ (fig. 318), *Canna*, and some other plants the embryo is contained in an inner central compartment or sac (sometimes called the amniotic sac), so that the perisperm is here double. The enclosed portion is sometimes called the *endosperm*; the development of this will be described in the Physiological part of this work.

The uniformity of the perisperm is also destroyed in some seeds by a peculiar lobulated condition of the outer portion, the sinuosities being filled up and enclosed in an inseparable layer of different-coloured tissue, giving a marbled appearance; this, which is seen in the Nutmeg, is called a *ruminated* perisperm or albumen. In the Cocoa-nut the perisperm is hollow when mature, containing the so-called milk (fig. 319).

The Embryo.—The *embryo*, or rudimentary plant contained in the seed, ordinarily possesses, when the seed is mature, all the essential organs of vegetation, namely root, stem, and leaves, although in a few cases the leaves are undistinguishable; while in others the embryo is a mere cellular nodule in the ripe seed, as in Orchidaceæ and Orobanchaceæ. The embryo is the result of the fertilization of the germinal vesicle or *oosphere* contained in the embryo-sac (p. 139).

Parts of the Embryo.—The end of the embryo usually pointing to the micropyle is the *radicle* (figs. 320–323, *a*) or rudimentary root, continuous with the lower end of the axis which terminates at the other end in the *plumule* (figs. 321–323, *c*) or rudimentary terminal bud. The axis itself is sometimes very short, being a mere "collar" between the base of the seed-leaves and the radicle; but, in some cases, it is developed into a well-marked *hypocotyledonary axis* or *tigellum*, distinguishable from the radicle by its cylindrical form (or, if conical, the point of the cone is upwards). The rudimentary leaves, called *cotyledons* (figs. 321–323, *b''*, *b'*, *b*), differ in number in the two great classes of Angiospermous Flowering plants, since in the Dicotyledons there are two placed face to face at the upper end of the axis, with the plumule between them (fig. 321); and in Monocotyledons only one exists (or the rudiment of another on a different level), and this is more or less completely rolled round the plumule, like the sheath of the leaf in Grasses (fig. 323).

The embryos of the Gymnosperms are either dicotyledonous, as in *Cycas*, *Taxus*, *Juniperus*, &c., or really or apparently *polycotyledonous*, as in *Pinus* (fig. 324), where it is said that the seeming whorl is formed of two deeply divided cotyledons.

Direction of the Embryo.—The embryo, whether covered only by

the coats or imbedded in perisperm, exhibits many varieties in the relative position of its parts: thus it may be *straight* (fig. 314), *curved*, *arcuate*, or *hooked* (fig. 325), *spirally coiled* (fig. 326), or *folded*; in

Fig. 323.

Fig. 324.

Fig. 325.

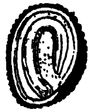


Fig. 326.

Fig. 323. Aperispermic Monocotyledonous seed of *Potamogeton*, with the coat removed: *a*, radicle; *b*, cotyledon; *c*, plumule.
Fig. 324. Embryo of *Pinus*, extracted from the perisperm, and the cotyledonary lobes separated.
Fig. 325. Vertical section of the seed of *Atropa Belladonna*.
Fig. 326. Vertical section of the seed of the Hop (*Humulus*).

the last case the radicle may be folded against the back of one of the cotyledons (*incumbent*, fig. 327) or against their edges (*accumbent*).

The *cotyledons*, which are usually of fleshy texture, and vary much in form, degree of expansion, and solidity in different cases, are occasionally rolled or folded up like leaves in leaf-buds (figs. 328 & 329); and these are described by the terms defined above under the vernation of leaves (p. 73). They are sometimes *foliaceous*, as in *Convolvulus* or *Ricinus* (fig. 320), &c. The fleshy kinds occasionally cohere very firmly in Dicotyledons in the mature state; and they are sometimes of unequal size, as in *Trapa natans*.

Fig. 327.

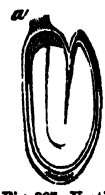


Fig. 328.

Fig. 329.

Fig. 327. Vertical section of the seed of *Erysimum*: *a*, funiculus.
Fig. 328. Dicotyledonous embryo extracted from a Turnip-seed.
Fig. 329. Dicotyledonous embryo extracted from the seed of the Maple (*Acer*).

Generally the cotyledons form the greater part of the embryo, as in the Bean (fig. 321); but sometimes they are very small or undistinguishable. They usually die away, but in *Welwitschia* they remain to form the only leaves the plant has.

Relative Position of the Embryo.—The embryo may be in the very centre of the perisperm (*Polygonum*), *excentric*; completely external (Grasses, fig. 315); curved round the outside *peripherical* (*Lychnis*, fig. 317). The radicle generally points to the hilum (*homoblastic*), rarely away from it (*enantioblastic*).

PART II.

SYSTEMATIC BOTANY.

CHAPTER I.

PRINCIPLES OF CLASSIFICATION.

Sect. 1. Species and Genera.

Systems of Classification.—In throwing plants together into groups, two methods may be adopted, constituting respectively an *artificial* or a *natural* system of classification. In the former, the only object is to arrange or place objects in such order that we may find them readily by some prominent mark, in the same manner as words are arranged alphabetically in a dictionary. In a Natural Classification, the object is so to combine our materials that the things brought closest together shall have the greatest possible agreement; from which it results that a knowledge of all the peculiarities of one carries with it the knowledge of *most* of those of its neighbours, and enables us, from the observation of a portion of the characters of a given kind, to foresee the rest. According to the derivative theory a group is natural in proportion to the accuracy with which it expresses the degree of relationship of the members of the group to each other, and of one group to its fellows. If there is no real kinship, the resemblance is only superficial, and the classification therefore artificial.

Species.—Systematic Botany is founded upon the real or assumed existence of distinct *kinds* or *species* of plants—a notion which of course belongs not to science exclusively, but is a part of the common experience of the world. But there is a great difference, practically, between the kinds of things accepted in the ordinary affairs of life and the kinds admitted in science, more especially in the Biological sciences.

There is another fact of daily experience which is of primary importance in reference to this point; that is, the circumstance that plants produced from seeds most commonly resemble in all important respects the parent plant from which the seeds were derived, and this through an indefinite number of generations; from which it follows that kinds or species of plants are regularly reproduced by their seeds.

The definition of a species can only be considered as arbitrary; but for practical purposes it may be said that a species consists of those individual plants which agree in all their important and constant characters, in the same way as do individuals of analogous structure, which we know to have descended through a number of generations from a common stock, and which therefore may be assumed to have been produced through seed from an original individual, or pair of individuals, of a distinct kind. To these may be added the assertions that individuals of the same species may be cross-fertilized, to the improvement rather than the detriment of the fertility of their seeds, and that they are affected in a generally similar manner by external agencies.

Diversity of opinion still exists amongst naturalists as to the origin and fixity of species. On the one hand it is assumed that every distinct species originated in a distinct creation of that form, which has been perpetuated, with its essential characters unchanged, through succeeding generations. It is usually added by the same school that, as regards plants, every species originated from a single prototype, or a pair of parents where the plant is diœcious.

On the other hand, it is contended by most modern naturalists that species were not necessarily created as we now see them, but that existing species are the lineal descendants of those that have gone before, and more or less modified in course of time by varying circumstances, such as inherent tendency to vary, the effect of external agencies, and the competition of other forms. This notion involves the conclusion that species are not absolutely invariable.

Varieties.—Species are distinguished by those characters which under present circumstances are constant so long as the conditions under which they exist remain unchanged; but individuals may possess other *additional* characters of less importance, which are inconstant. Even as in the human species we find every individual possessing certain peculiarities, so even in almost to the lowest of created beings do we find what is called an idiosyncrasy, and individual character, chiefly depending, in the vegetable kingdom, upon the conditions under which they have grown up. We often find seeds from the same parent producing individual plants differing in the colour, size, and number of their flowers and of their vegetative organs, according to the conditions of climate and soil to which we submit them. Very often, moreover, we find these differences displaying themselves under what appear to us identical conditions, as is particularly the case with many of the favourite "florist's flowers"—such as the *Pelargonium*, *Fuchsia*, Pinks, Asters, &c.,

which "sport" out into numberless varieties when raised from seed under highly artificial conditions. The occurrence of such variations is less common and, when it occurs, generally less marked in wild plants, as might naturally be expected, from the likelihood of wild plants maintaining their footing best in a position where the conditions are most natural to them; but we do find remarkable cases of variation in many wild species, as of colour in the common Milkwort and the Columbine (*Aquilegia*); but most of those kinds which exhibit the tendency now and then in a wild state, become extremely variable under culture. Some of the variations are dependent simply upon modifications of the cell-contents of certain tissues, as in the commonest of all variations, those of colour, and in the not uncommon appearance of white patches and streaks ("variegation") on the leaves. Other variations are teratological, and result from the over-stimulation of the vegetative system, causing the reproductive organs to degenerate (of which the ordinary "doubling" of flowers by the degradation of their stamens into petals is an example)—or, *vice versâ*, the application of stimuli at particular epochs, producing remarkable development of flower or fruit. All these variations, more especially those involving serious teratological changes, tend to disappear. Common variations, of slight importance, mostly die out at once in the descendants through seed, especially if the conditions are varied; serious departures from the typical structure (teratological variations) lead to barrenness and incapability of continuing either the variety or the species by seed.

It is important to note here a fact which will be more minutely examined in another place, namely, that although the peculiar characters of varieties are commonly lost in seeds, the peculiar form is capable of indefinite propagation by vegetative multiplication through cuttings &c., the special idiosyncracy being possessed in common throughout all the leaf-buds, both while forming part of the parent and after they have been detached from it to form new plants, grafts, &c.

A certain number of species which vary more or less in a wild state exhibit a remarkable peculiarity under systematic cultivation. By strictly maintaining a certain set of conditions, varieties originating accidentally or through intentional treatment are made to manifest their additional peculiarities so strongly, that they transmit the tendency to present similar peculiarities to their seeds; and such transmission goes on for an indefinite number of generations, provided the requisite external conditions are kept up. In this way arise what are called *Races*, series of individuals connected by common characters and by inheritance, like species; but, unlike them, liable to lose, in one or a few generations, under change of conditions, part or all of the essential characters by which they are distinguished. We have examples of such races in most of our esculent vegetables, especially in the many varieties of form, more or less permanent, derived from the wild Cabbage (*Brassica oleracea*).

These, together with *Hybrids*, or the produce of cross-fertilization between individuals of distinct species, will be referred to again among the phenomena of the Physiology of Reproduction. The determination of the limits of species is greatly obstructed in many cases by the frequent occurrence of varieties, and more particularly of races—to which hybrids add another complication, probably of less importance than many modern authors suppose. It appears probable that the number of real species is

far smaller than is usually supposed, and that many races, and a large number of frequently recurring varieties, hold a place in our existing lists of species. The varieties and races above mentioned are considered under the development hypothesis as the initial stages in the formation of new species. If these variations are of such a nature as to enable the plant to adapt itself better to the conditions under which it lives, or to sustain itself in the battle of life with other organisms, then they will be perpetuated—become more constant, and ultimately attain such a degree of relative constancy or invariability as to be classed as species.

Genera.—Whenever we examine a large assemblage of distinct species, we shall find that certain of these agree with certain others more closely than with the rest; so that we may parcel them out into groups, in each of which we shall find an agreement in a number of common characters, by which it is also distinguishable from the other groups. Generally speaking, we shall find that we can place together a number of species agreeing closely in the essential plan of construction of their *floral organs*, while they differ in the forms and duration of their *vegetative organs*, &c. Groups of this kind are called *genera*; and the notion of a *genus*, like that of a species, is not only common to all departments of human knowledge, but is also existent in the language of common life in its special natural-history sense, only requiring for scientific purposes to be more strictly defined. In every language we find *generic* names applied to plants, such as Willow, Rose, Violet, and a hundred others, each of which terms is indicative of a group of kinds or species, more or less extensive in different cases, corresponding exactly in its logical value to the *genus* of the botanist.

Some of these groups are characterized by very striking peculiarities, so that even the genera of vulgar language correspond very nearly with those of the botanist; but in the generality of cases the popular collective names are applied on superficial grounds of resemblance, and include widely diverse species. For example, the term Violet is made to bind together not merely the common scented and other true Violets, but the Dame's Violet (*Hesperis*), a plant of the Cabbage family, the Calathian Violet (*Gentiana Pneumonanthe*), a true and characteristic Gentian, the Dog's-tooth Violet (*Erythronium Dens-Canis*), a plant of the Lily family, &c.; while the term Rose is extended from true Roses to *Cisti*, or Rock-roses, Rhododendrons, Alpine Roses, &c. It is obvious here that there can be no near "blood relationship," if we may so term it, between these so-called Roses, &c. The classification of all these forms having only superficial resemblance to each other is a purely artificial classification. Still some genera are characterized in a sufficiently marked way for most of their constituent species to be recognized as such pretty readily, after a very small amount of attentive examination, as, for example, true Roses, Willows, Lilies, &c.; and we call such genera, including species of a very marked similarity, "natural genera," thus indicating the closeness of the band that ties them together. On the other hand, the principle of combination which accords with the intuitive classification in those

natural genera leads to the establishment of other genera wherein the species seem at first sight to differ widely, of which we could not have a better example than in the genus *Euphorbia*, where our native species are inconspicuous herbs, while the tropics afford species with large spiny Cactus-like trunks, &c.

Moreover the carrying out of the same principle leads in certain cases to the generic separation of species which present close agreement in their general characters, but are distributable into a number of groups characterized by very decided morphological diversities in important parts of their floral organs. Thus, in the Umbelliferæ, the Compositæ, the Grasses, and some other families, we separate generically species which have a great resemblance in the majority of their characters. This happens especially in what are called *very natural families* of plants, large assemblages of genera so evidently connected with each other by the presence of some very marked peculiarity, such as the Umbelliferous inflorescence, the Papilionaceous corolla of the Leguminosæ, the Capitulous inflorescence of the Compositæ, the peculiar spikelets in the Grasses, &c., that no doubt can be entertained as to their lineage. On the other hand, the "natural genera" occur mostly where the character of the natural family is more lax and flexible, as in the Ranunculaceæ, Rosaceæ, &c.

In the present state of knowledge it must be admitted that a very large portion of our generic distinctions are arbitrary, and that the species included in some genera agree together much more closely than those combined under other generic heads. At the same time it cannot be doubted that some genera are really far more extensively represented by species than others; so that the mere number of kinds included in a genus is to be totally neglected in a natural classification; and many recent authors have done disservice to science in general by splitting up large natural genera on slight characters for the convenience of systematists. It is far more instructive to keep together the members of large natural genera, like *Ficus*, *Erica*, *Begonia*, &c., than to subdivide them under names which disguise their relations; and the convenience of systematists may always be sufficiently regarded by the establishment of *sections* in extensive descriptive works.

Genera are groups of species associated on account of agreement in the essential characters of their floral organs; but here, as elsewhere in nature, variations from our abstract types must be admitted. Some undoubtedly natural genera include species with their floral organs varying in certain particulars more than is usual in groups associated under a common type, somewhat as certain species admit of a wider range of variation than others. Here, again, physiological characters become of value; and as in species we regard the fertility of the seeds produced by unlimited cross-breeding between the varieties as a proof of these being individuals of the same species, so with regard to genera it is commonly held that a generic connexion between diverse species is indicated by the capability of producing *hybrids* by cross-breeding. These true hybrids produced between distinct species of the same genus are often barren, or only breed with individuals of one of the parent

species, which soon eliminates the cross, and leads to a complete reversion to that species.

The physiological test is consonant with morphological evidence. Individuals of the same species are capable of indiscriminate fertilization because they are exactly alike in all essentials of structure. In hybrids produced between two species of a genus, the parents agree sufficiently in structure to allow of their producing a few fertile seeds; but the plants raised from these seeds contain two contradictory impulses, which so far prevent the perfection of their organization that they either remain barren or a dissociation of the mixed characteristics occurs with, it may be, their ultimate entire extinction.

Origin of Species—Selection.—Supposing species to have originated from a few primordial forms, from which all existing species have been derived, just as individuals may be traced back to a common parent stock, the question then arises as to what causes have produced the modifications. Where, on this hypothesis, there were originally a few, or perhaps a single primordial form, to which all then existing individuals might have been referred, there is now an infinite number of forms both in the animal and vegetable kingdoms. How have these arisen? To this question the answer given by various naturalists has been different.

By some the variations have been attributed to the influence of external conditions; by Darwin to an innate tendency, producing variations of structure, some of which, under given circumstances, would be favourable to the progress and development of the individual, and others not so. In the battle of life, the struggle constantly going on in animated nature, those variations most advantageous to the organism in its competition with others would be preserved by "natural selection," while other variations of less advantageous character would be obliterated or not perpetuated. Hence the victory would be to the strongest; the weakest would go to the wall, and the result would be, in Mr. Spencer's language, "the survival of the fittest." It will thus be seen that on this hypothesis species are not considered immutable, and variations, especially such as are advantageous to the organisms, are regarded as the starting-points of new species. With reference to these points the student will do well to bear in mind that these and kindred speculations are not to be treated as dogmas or creeds, but as means to an end, and that end the more perfect knowledge of the origin and relation of existing forms. Any hypothesis or theory which will serve to correlate and bind together a number of otherwise isolated facts and explain their interdependence, is valuable not only for what it effects at the time, but as a focus around which other facts may in future be gathered. That hypothesis is best which serves to give a rational explanation of the largest number of observed phenomena of the greatest importance. Tried by this test, the Darwinian hypothesis, or, rather, the theory of evolution, has great advantages, and presents on the whole fewer difficulties and less inconsistencies than the older hypothesis of separate creation of each species. Particularly does this seem true in the case of the subject now before us—the classification of plants. The admission of the principle of filiation and genealogical descent gives the natural system of classification a clearer claim to its title of "natural" than it had before, supplies the explanation

of a vast number of phenomena otherwise inexplicable, and offers plausible and valid reasons for the existence of facts and processes that were previously considered either unintelligible or purposeless modifications of an assumed structural type. The portion of Mr. Darwin's hypothesis which has perhaps received the least amount of assent has been that relating to natural selection. The idea was based on that artificial process of selection by means of which man has been enabled progressively to improve and perpetuate the different forms of domestic animals and cultivated plants. In the latter case the horticulturist is ever on the look-out for variations. If he sees one that suits his purpose, such, for instance, as a plant producing larger flowers than ordinary, he does all that he can to perpetuate that variety by carefully selecting seed from it, at the same time that he destroys or neglects other less desirable variations. In this manner, after a time, the selected variety becomes "fixed," and a "race" is formed. On the Darwinian hypothesis a selective process is supposed to occur naturally, similar to that employed by the gardener or agriculturist as just explained, such selection or elimination resulting, as before said, in the survival of the fittest.

Sect. 2. Nomenclature.

Names of Plants.—The Terminology of Botany establishes rules for naming the parts or organs of plants, and the different characteristics which those organs present. Nomenclature deals with the naming of plants themselves as members or parts of the Vegetable Kingdom; and it furnishes the rules for naming the kinds of plants, and the various groups or assemblages in which they are associated in our systematic classifications of kinds.

The primary rule in botanical (and zoological) nomenclature as laid down by Linnæus is, that *every species shall have a particular name, compounded of a substantive and an adjective* (or substantive used adjectively), *whereof the former indicates the genus, and the latter the species.*

This rule of naming may be compared with the common usage of surnames and christian names—the former indicating the family to which a man belongs, while the latter admits of his being spoken or written about without the necessity of adverting, except for special purposes, to his personal peculiarities or his relationship to the other members of his family.

These scientific names of plants were originally established in Latin, because Latin was the general language of science at the time they were introduced; and they will be retained with advantage so long as diversity of language exists, since they ensure to all plants and animals names which have universal acceptation, and which, like the Arabic numerals 1, 2, 3, &c., are equally comprehensible to the educated of all nations, and, moreover, they are more definite and precise in their signification than ordinary vernacular appellations.

Generic Names.—The substantive names of genera have been and are still formed very arbitrarily, and without any generally recognized principle.

All those which have been identified as known to the ancients are called by their classic names, such as *Prunus*, *Myrtus*, *Quercus*, *Thymus*, &c., the etymology of which is more or less obscure in various cases. A very large proportion of modern generic names are founded upon combinations of Latin and, more particularly, Greek words indicating some obvious external peculiarity, or some property possessed, or supposed to be possessed, by the plants; but the application of this principle has often been carried out without accurate knowledge and without happiness in selection, so that many such names are but little characteristic, and would often apply more correctly to other genera. Those, on the contrary, which are well chosen afford a certain assistance to the memory; examples of such names, founded on structure, occur in:—*Lithospermum*, so called from its stony fruit (or supposed seed); *Campanula*, from its bell-shaped corolla; *Sagittaria*, from its arrow-shaped leaves, &c.: on qualities, in *Glycyrrhiza* (Liquorice), from its sweet rhizome; *Rubia* (Madder), from yielding a red dye; *Lactuca* (Lettuce), from its milky juice, &c.: or on accustomed station, as *Arenaria*, *Epidendrum*, &c.: others have derived their names from supposed medicinal powers, such as *Pulmonaria*, *Scrophularia*, &c.

Another large class of generic names is founded on proper names either of mythological or real personages, more especially distinguished botanists, to whom the genera are dedicated. Linnæus drew largely upon classical mythology and legendary history as a ready source of diverse names for the many newly defined genera he had to deal with; and the names *Iris*, *Artemisia*, *Amaryllis*, *Narcissus*, &c. stand out strongly in their euphony from most of those founded on modern names; such names, however, as *Linnæa*, *Lobelia*, *Dioscorea*, *Magnolia* go far to rescue the principle of naming genera after botanists and their patrons from the opprobrium brought upon it by such as *Schumacheria*, *Schweyckherta*, *Razoumowskia*, *Eschscholtzia*, and the like, and will probably be preferred by most persons even to such "characteristic" names as *Pleuroschismatypus*, *Oxystophyllum*, *Pachypterygium*, *Glischrocaryon*, &c.

In face of these last, the pseudo-Latin barbarisms *Thea*, *Coffæa*, *Bambusa*, which preserve the original native names of plants, become no longer uncouth.

Specific names are always either *adjectives*, or *substantives used adjectively*. When they are adjectives, they must of course be made to agree with the substantive; and it may be recalled to recollection that in Latin all names of *trees* are *feminine*, whatever may be the termination.

In the majority of cases, the specific names are selected on similar grounds to the generic. Attempts are very commonly made to render the name characteristic, a proceeding which in many cases affords a certain advantage; but when, on the contrary, it is carried out in im-

perfect acquaintance with the species of large genera, it leads to confusion. Sometimes these names indicate the character of the *leaves*, as in *Tilia grandifolia* and *parvifolia*, or the existence of a definite number, as in *Platanthera bifolia*, *Paris quadrifolia*, &c.; or the character of the *inflorescence*, as *Butomus umbellatus*, *Bromus racemosus*, &c. Or the "habit" of a species is indicated by such adjectives as *major*, *minor*, *scandens*, &c.; or its duration, as by *annua*, *perennis*, &c.; and in some cases comparisons with other plants are marked, as in *Ranunculus aconitifolius*, *Acer platanoides*, &c.

Generally speaking, the colour of flowers is too variable for specific distinctions; but nevertheless many species are named from their usual or constant colour, as *Gentiana lutea*, *Lamium album* and *purpureum*, *Digitalis purpurea*, &c.

Station, *i. e.* kind of soil or place inhabited by a plant, is another source of names, as *arvensis* (common on ploughed land), *agrestis*, *hortensis* (on cultivated ground generally), *pratensis* (in meadows), *sylvestris* or *sylvaticus* (in woods), *palustris* (in swamps), *aquaticus* (in or about water), and *sativus*, a term commonly applied to kinds regularly cultivated from seed. Most of these terms are applied vaguely, and a similar want of accuracy in the implied idea affects many of the names founded on the places where plants have been first observed, such as *Silene gallica*, *Stachys germanica*, *Genista anglica*, &c., none of which are peculiar to the countries named, though they may, in the first instance, have been considered to be so.

Such names as *odorata*, *suaveolens*, *fœtida*, &c., expressing marked qualities, were formerly much used; and the adjective *officinalis* is found applied to a host of plants formerly valued by the herbalists for some supposed medicinal or economical property.

Substantive names used adjectively are mostly names of abolished genera, retained in association with the new generic term, as *Ranunculus Flammula*, *Pyrus Malus*, *Matricaria Chamomilla*, *Prunus Cerasus*, &c.,—these old generic terms being in a few cases double, as *Adiantum "Capillus-Veneris," Lychnis "Flos-cuculi,"* &c. Or substantive proper names are used in the genitive case, as *Limnocharis Humboldtii*, *Viola Nuttallii*, *Galium Vaillantii*. The dedication to distinguished persons may, however, be effected by adjectival terms, as *Salix Doniana*, &c., the use of the genitive noun being more strictly appropriate when it is the name of the discoverer or first describer of a species, the termination *ana* conveying a mere compliment and not necessarily implying that the person to whose name it is affixed had any thing to do with the particular plant in question.

Authorities for Names.—If the rules of scientific nomenclature were strictly enforced under the direction of a single authority, each plant would have but *one* name (composed of the generic and specific appellations), and this name would be indissolubly and unequivocally connected with the idea of the peculiar species. But it happens practically that such is not the fact, and this for reasons necessarily affecting various cases. Not unfrequently it happens that a plant possesses more than one *specific* name, which may arise from an author naming it a second time, through entire ignorance of its having been previously observed, or from his erroneously supposing a particular form to be distinct from the already known and named species. Almost as frequently in the present day do

we find a distinctly recognized species denominated by more than one *generic* name, while the specific appellation remains the same, this ambiguity arising from difference of opinion as to the limits of genera, and consequently as to the group to which particular species are to be referred.

To ensure accuracy, therefore, it becomes necessary, whenever the name of a plant is mentioned in a scientific work, that the *authority* for the name (that is, the author who originated it, or whose peculiar application of it we adopt) should be indicated. This is done by subjoining an abbreviation of his name. Thus, *Bellis perennis*, Linn., or L.; *Inula Conyza*, DC.; *Pulicaria vulgaris*, Gaertn., signify that we mean the species which were defined under these names by Linnæus, De Candolle, and Gaertner, respectively. In like manner it is requisite, in the majority of cases, where the name of a genus is mentioned, to indicate the authority, since many of the older genera of Linnæus and others have been broken up into a number of groups, and the original name restricted to one of these more limited assemblages.

Synonyms.—The superfluous or incorrect names which exist in many cases cannot be neglected where they have once acquired a certain currency, because a certain amount of existing knowledge is connected with these names in the works of the writers who have used them. Hence arises the necessity of enumerating the *synonyms* of plants. The citation of synonyms is of course unnecessary in general cases, where the names of plants are incidentally mentioned, so long as the authority for the name is given; but in Systematic works, such as descriptions of the plants of a country or province, or monographs upon particular groups of plants, it is part of an author's duty to ascertain and indicate all the names which have been applied to the particular forms, and the exact senses in which different names have been employed. The synonyms subjoined to a specific name may indicate:—1, that the same species has received different names from different authors; 2, that a selected specific name includes the several supposed or real species enumerated under it; 3, that the species has been removed from a genus to which it was formerly referred; 4, that a particular view is taken both of the generic and specific value of a plant concerning which opinions have varied in both particulars.

The following examples may serve to illustrate this:—

1. The name *Galium verum*, L., has simple priority and therefore preference over *G. luteum*, Lamarck, indicating the same species, which was accidentally or erroneously named by the latter author *after* Linnæus had given it an appellation.

2. *Agrostis alba*, L., includes *A. compressa*, Willd., *A. gigantea*, Roth, *A. stolonifera*, L. (in part), &c.; these latter have been mistakenly separated from it, or subsequently named without knowledge of the identity.

3. *Castanea vulgaris*, Lam., is now substituted for *Fagus Castanea*, L., as the genus *Castanea* is now regarded as distinct from *Fagus*. In many

cases we find a distinct generic name given as a synonym where it is really more recent, but is rejected in favour of the older on the ground that the more recent generic separation is not approved of; for instance, *Apargia autumnalis*, Willd. (*Oporinia autumnalis*, Don).

4. *Catabrosa aquatica*, Beauv., is named in diverse works *Aira aquatica*, L., *Molinia aquatica*, Wibel., *Poa airoides*, Koel., *Glyceria aquatica*, Presl, &c.

The multitudinous synonyms which fall under the last category are attributable to the excessive tendency of modern writers to multiply genera on slight grounds. Such minor subdivisions are far better restricted to extensive systematic works, on the plan adopted in De Candolle's 'Prodomus,' providing them with sectional names for the exclusive use of systematists, and preserving the more general name for common purposes.

Nomenclature of Varieties.—The varieties of species are noticed in descriptive works when of frequent occurrence, and then are either simply indicated by the letters of the Greek alphabet, or have an additional adjective name like the species, which plan is especially followed in lists of garden varieties. In such cases either the ordinarily occurring form is taken as the type, and the series of occasional varieties is begun with β, as—

Sambucus nigra, L. ——, var. β. leaflets laciniated (Hooker & Arnott).

or, *Sambucus nigra*, L. —— β. *virescens* (fruit green). —— γ. *leucocarpa* (fruit white). —— δ. *laciniata* (leaflets laciniated). —— ε. *variegata* (leaves with white streaks), Koch.

Or if the species is variable and no one form is considered typical, the series begins with α, thus:—

Fedia dentata (Hooker & Arnott). —— α (*Valerianella Morisonii*, DC.). —— β (*Fedia mixta*, Vahl). —— γ (*Fedia eriocarpa*, Rœm. & Sch.).

The nomenclature of cultivated plants is fruitful in examples of named varieties in large numbers belonging to particular species, such as *Clarkia pulchella alba*, *C. pulchella rosea*, &c. &c.; but these names are often applied without scientific exactitude.

Hybrids are named according to certain rules when they occur frequently wild or, if obtained artificially, when they are propagated by cuttings, bulbs, &c. The names of the two parent species are combined, thus:—*Verbascum nigro-Lychnitis*, a hybrid between *V. nigrum* and *V. Lychnitis*. With regard to artificially produced hybrids, it is possible to indicate the parentage with more accuracy, and the name of the seeding plant stands before that which yields the pollen, as *Amaryllis vittato-reginæ*, the form produced when the ovules of *A. vittata* are fertilized by the pollen of *A.*

reginæ, and *vice versâ*. Where a plant is known to be of hybrid origin, it is a good plan to indicate the fact by prefixing × to the name.

The nomenclature of the groups above genera is of less importance than that of genera and species, and is dealt with more independently by individual writers. Artificial groups are generally named from the character on which they are founded, as in the case of the Linnean classes and orders. The same is the case with the artificial divisions which are used in most Natural Arrangements for conveniently subdividing large assemblages of Families or Orders, such as *Thalamifloræ* &c. of De Candolle, *Polypetalæ* &c. of Jussieu. But as the essence of the Natural Arrangement of plants lies in the combination of forms according to the majority and importance of points of likeness or general character, we are not necessarily restricted by any definite character in the selection of the name; and in regard to the Natural Orders, great diversity of principle has prevailed in the application of the names, and even considerable latitude in the form given to them. There exists, however, one rule applied in all Latin naming of what are termed Natural Orders: the word *plantæ* is *understood*, and an adjective name agreeing with this represents the group. In existing systems we find these adjective names founded sometimes on a prevalent character in the family, as (plantæ) Leguminosæ, Coniferæ, Umbelliferæ, &c.; sometimes on the names of typical genera, as Rosaceæ, Solanaceæ, Convolvulaceæ; sometimes on an existing general name derived from common language, as Graminaceæ and Palmaceæ. A difference of termination exists even in regard to the same word in different authors: thus, one author writes Cistineæ, another Cistaceæ, with the same meaning; while others use the word Aroideæ in preference to Araceæ, or Palmæ in preference to Palmaceæ.

Attempts have been made to reduce all these names to a system, and to preserve the same form of termination for groups of the same value. Thus it is proposed to make the names of all Orders end in *aceæ*, like Ranunculaceæ, Ericaceæ, &c., the only objection to which is the necessity of discarding many familiar and well-established names, and replacing them by strange ones, as Apiaceæ for Umbelliferæ, Fabaceæ for Leguminosæ, &c. "Classes" or "Alliances" again are made alike by using the terminal form *-ales*: as Glumales, instead of Glumaceæ or Glumiferæ, for the group composed of the Orders with a glumaceous perianth, &c.

A fixed rule does exist among all modern writers in the denomination of *suborders* or *tribes* into which Orders are divided; for these are founded on typical genera, the names of which are made to furnish adjectives by the substitution of *eæ* for the last vowel and whatever may follow it: for example, in the Order of the

Ranunculaceæ, we have the tribes *Anemoneæ* from *Anemone*, *Ranunculeæ* from *Ranunculus*, *Helleboreæ* from *Helleborus*, &c.; and in botanical works these names of tribes are commonly printed in *italics* like those of genera and species, while the names of families and all above them are printed in roman letters.

The names applied to the larger divisions of the Vegetable Kingdom in Natural Arrangements are generally made as characteristic as possible; but, as will be shown in the Section on Natural Arrangements, none of the single characters of such groups are absolute, and therefore no name founded on one character can be universally descriptive. Thus the name Monocotyledones is applied to a most natural group, in which are, however, included one or more orders, as the Orchidaceæ, in which the embryo has no cotyledons. And it may be said that to an advanced student it is far more beneficial to regard all names as abstract signs, used rather to indicate certain plants or groups of plants with which he is acquainted, than as expressive of the characters of the plants to which they are applied.

These observations on the nomenclature of the Orders and higher groups of plants are placed here for the sake of connexion with the remainder of the subject; but they will be better appreciated after acquaintance is made with the illustrations of them in succeeding Sections.

Sect. 3. Description of Plants.

It is the business of every botanist who distinguishes and names a new species of plant to furnish an exact statement of the characters by which it may be recognized by others.

The most complete fulfilment of this requisition is supplied in what is termed a *description* of a plant, in which is given a detailed account of the external form, the arrangement and relations of all its organs, according to a fixed plan and in a fixed language, furnished by the terminology made use of in Morphology.

In order to impress upon the mind of the student the principal points to be looked to in describing a plant, and thus to ensure completeness and accuracy of observation, we subjoin a list of the more salient characteristics which it is desirable to notice in writing a full description of a plant. Some of these are of much greater importance than others, inasmuch as they afford the means of grouping plants into genera and orders, not only physiologically but morphologically, &c., and furnish what are called *diagnostic characters*. From their great importance, much stress is deservedly laid on them; hence, after enumerating the principal "characters" necessary to be ascertained in drawing up a full description, we shall insert illustrations of the "schedules" introduced with so much success for teaching-purposes by the late Professor Henslow, and in which attention is drawn solely to those points of special importance.

It must also be borne in mind that the terms used are such as are in general use, and are to be taken in their conventional sense, and not as

necessarily expressing the exact truth: thus, as has already been explained under the head of Morphology, when we say that one organ is *inserted into* another, it would be more correct to say that the one emerged from the other; in the same way many cases of so-called *cohesion* and *adhesion* are shown, by the study of the progressive development of the flower, to be rather cases of arrested separation than of union of originally distinct organs.

In describing a plant fully, a commencement is made with the root, from which we proceed to the stem, leaves, inflorescence, flowers, and, finally, the ripe fruit and seeds.

In the case of the *root* the principal points to be looked to are:—first its *nature*, whether true or adventitious; then, in succession, its *form*, *direction*, *size*, degree and mode of *ramification*, *duration*, *consistence*, *surface*, *colour*, &c. Similar remarks apply to the *stem* and its modifications.

Leaves require first to be noted as to their *position*, radical, cauline, &c.; *insertion*, stalked or sessile; possession or deficiency of stipules; *arrangement*, alternate, opposite, &c.; *composition*, simple or compound; *direction*, *duration*, *texture*, *colour*, and *surface*. The *blade* of the *leaf* must then be described as to its *general form*, *outline*, *base*, *apex*, *margins*, *mode of venation*, *size* (especially in relation to the stalk, if present). The subdivisions of a compound leaf must be treated in the same manner as simple leaves. The *petiole* or leaf-stalk has to be noted as to its *form*, *surface*, *relative size*, &c. *Stipules*, as far as practicable, should be described in a similar manner to the leaves, as also should, *mutatis mutandis*, the *leaf-buds*. In their case, as also in the case of *flower-buds*, the mode of *vernation* or of *æstivation*, as the case may be, should be ascertained and recorded. As regards the *inflorescence*, the principal things to be considered are its *position*, *direction*, *relative size* as compared with the leaf, *nature* (definite or indefinite), *ramification*, *form*, *number of flowers*, *duration*, &c.

The *flower-stalks* follow the same rule as the leaf-stalks; but particular attention should be paid to the top of the flower-stalk (the *thalamus*) to see whether it be flat, convex, or concave. The *bracts* are described in the same manner as the leaves. In the case of the *calyx* and *corolla*, attention should be directed to their *construction* (cohesion), *relative position* (adhesion), *form*, *direction*, *colour*, *venation*, *surface*, *size*, absolute and relative, *duration*, *odour*, &c.

Individual *sepals* or *petals* should be described in the same way as the leaves.

Stamens should be described with reference to their *insertion* (adhesion), *cohesion* (free or united), *number*, *position*, *arrangement*, *size* (with reference to one another and to the other parts of the flower). *Filaments* present similar characters to those offered by the leaf-stalks, and are described accordingly. *Anthers* require attention as to their *form*, *mode of attachment* to the *filament*, *shape* and *number* of their *lobes*, their *mode of dehiscence*, *colour*, *surface*, the form and peculiarities of the *connective* and of any appendages that may be present. The *form*, *colour*, and distinctness or cohesion of the *pollen-grains* should, if possible, be stated. This is not always practicable unless recourse be had to the compound microscope, when other peculiarities, then visible, should be noted, as will be further explained in the section on Physiology.

After the stamens, the characteristics of the *disk*, if present, should be

noted, and then those of the *pistil* as follows—*number* of the constituent carpels, their *isolation* or *cohesion* and *arrangement*, their *adhesion* and *relative position*, *form*, *cavities*, *partitions*, and mode of *placentation*. The *styles* require to be noted with reference to their *position*, *number*, *size* (*relative* and *absolute*), *form*, *surface*, *colour*, &c. Similar remarks apply to the *stigma*. The *ovules* differ in their *position*, *mode of attachment*, *number*, *form*, &c. The *fruit* follows the same rules as the pistil; but, in addition, the *texture*, *mode of dehiscence*, and *number of seeds* must be noted.

Seeds are described much in the same way as ovules, taking care not to overlook any of the peculiarities presented by the *coverings* of the *seed* in the way of hairs, scales, arils, and the like: the interior of the seed also requires special attention, to see whether or not it be *albuminous* or *exalbuminous*; if the former, the nature and quantity of the *albumen* should be noted; and in any case, where possible, the *form*, *position*, *direction*, *size* of the *embryo* and its parts, the nature and number of the *cotyledons*, &c. should be accurately ascertained.

The student is recommended to take any plant he meets with, and endeavour to draw up a description of it with reference to the foregoing scheme. By comparing the description of one plant with that of another he will familiarize himself with the main points of difference between one plant or one organ and another, and will learn to apply the appropriate *term* to each modification.

The subjoined description of the common white Dead-Nettle (*Lamium album*) is given as an illustration of a tolerably complete description of the external peculiarities of a plant; it may serve as a model to the student in drawing up similar descriptions. It is, however, advisable that he do not attempt too much at once. A bad or careless description is almost worse than none at all; hence the beginner is recommended to make himself pretty thoroughly acquainted with the peculiarities of such organs as are most easily studied before passing on to organs such as ovules, &c., which require some considerable practice before their structure and characteristic features can be ascertained.

Lamium album.—A rather coarse hairy perennial, with a shortly creeping *stock*, from the joints of which, especially on the lower surface, proceed at intervals numerous slender, fibrous, brownish *roots*. *Stems* 1–2 feet high, herbaceous, decumbent or ascending, fistular, four-sided. *Leaves* exstipulate, opposite, stalked, the upper ones nearly sessile, hairy, membranous, ovate-acute or acuminate, cordate, coarsely and irregularly toothed, unicostate, arch-veined, 2–3 inches long, 1–2 inches broad. *Petiole* less than half the length of the blade, channelled on the upper surface, rounded beneath. *Flowers* pure white, sessile, in axillary cymose whorls (verticillasters) of 6–10 or more. *Calyx* campanulate, of 5 sepals, united below into a *tube* traversed by 10 ribs; *limb* divided above into five nearly equal, spreading, linear, ciliated segments, of which the uppermost stands slightly apart from the others. *Corolla* white, tubular, bilabiate, twice the length of the calyx; *tube* curved, ventricose, as long as or longer than the calyx, scabrous inside, with a ring of hairs near the base; upper lip erect, concave, notched, hairy on the outer surface; lower lip spreading, 3-lobed, the middle lobe broad and 2-lobed, the two lateral ones small and pointed. *Stamens* 4, didynamous, epipetalous; *filaments* downy, springing from the upper part of the tube of the corolla, partially concealed within the upper

lip. *Anthers* innate, 2-lobed; lobes superposed, oblong, blackish, introrse, dehiscing longitudinally; *connective* covered with white hairs. *Pollen* yellowish white. *Ovary* small, truncate, 4-lobed, 4-celled, encircled at the base by a pale green, cup-like disk. *Ovules* solitary in each cell, anatropal. *Style* single, basilar, thread-like, as long as the corolla, terminating in a 2-lobed stigma; lobes of the stigma short, oblong, pointed. *Fruit* of four (or fewer by abortion), 1-celled, 1-seeded, indehiscent, blackish shining lobes or achenes. *Seeds* solitary, erect, inverted, exalbuminous. *Embryo* straight; *cotyledons* large, plano-convex; *radicle* short, inferior.

Such descriptions are now usually given in a modern language when occurring in works descriptive of the plants of particular countries and intended for general use, &c. In general systematic works, or in isolated notices, published in periodicals or Transactions, addressed more particularly to proficients, the Latin language is usually preferred, as it is understood by botanists of all nations and is less vague in its application.

Detailed descriptions are commonly given only where new species are established, or when an uncertain nomenclature is to be made clear and definite, in a monographic or a general systematic work. The classification of plants into genera, families, &c., in the Natural System, renders the repetition of the peculiar marks of these groups unnecessary in the characterization of the subordinate groups or forms. For this reason, *characters* and *diagnoses* commonly replace the complete descriptions of species in ordinary descriptive botanical works, since, as the character of the genus includes those peculiarities of the floral organs which are common to all its species, and which constitute the bases of the genus, it is only requisite to connect with each species the character by which that species is distinguished from others.

The following condensed description of the white Dead-Nettle, from Bentham's 'Handbook of the British Flora,' will show how, when the characters of the order and genus are known, a faithful portrait of the species, and one comprising the most conspicuous features only, may be drawn up:—"A rather coarse hairy perennial, with a shortly creeping stock, and decumbent or ascending branching stems, seldom above a foot high. Leaves stalked, coarsely crenate. Flowers pure white, in close axillary whorls of 6–10 or more. Calyx-teeth fine, long, and spreading. Tube of the corolla curved upwards, and longer than the calyx, with an oblique contraction near the base, corresponding with a ring of hairs inside; the upper lip long and arched; the lateral lobes of the lower one slightly prominent, with a long fine tooth." Then follows an account of the *station* in which the plant is found, and of its geographical distribution throughout this country and the continent.

Value of Characters.—Having gained a general idea of what points are to be looked to in drawing up a description of a plant, and having acquired a familiarity with the meaning and application of terms, it is particularly desirable that the student should be able to form an estimate of the *relative value* and *importance* of characters for practical purposes: for

instance, those characters which serve to identify and distinguish large groups of plants are of more consequence than such peculiarities as pertain merely to small groups or to individual plants. With a view to fix the attention on the more important or cardinal characters, those which are of most use in drawing up a *diagnosis* of a plant or of a group of plants, a form of schedule is given; and the pupil is recommended to make similar ones for himself, and by their aid to draw up an account of the more important characters of any flowers he meets with, checking them and comparing them with the descriptions given in books, or with the instructions of his tutor. These schedules should be kept for comparison with others relating to other plants; and by this method a practical insight into plant-construction, and the relationships of one plant to another, may be more speedily and thoroughly obtained than by any other means. The schedules here inserted by way of illustration are filled up from a Common Buttercup (*Ranunculus*) and from a Dead-Nettle (*Lamium*). The characters therein given are sufficient to enable the student to determine the *orders* to which the plants belong, which is the first and most important consideration; but they are not sufficient to indicate the *genus*, still less the particular species. To discriminate these minor groups, recourse must be had to the other peculiarities presented by the plants in question, as before detailed.

Ranunculus (Buttercup).

Organ.	Number.	Isolation.	Arrangement.	Insertion.	Cohesion.	Adhesion.	Form.
Calyx	polysepalous	...	...	...	...	...	regular.
Sepals	5	distinct	verticillate	hypogynous	...	...	...
Corolla	polypetalous	...	...	...	...	...	regular.
Petals	5	distinct	verticillate	hypogynous	...	...	...
Stamens	polyandrous	...	...	...	...	...	...
Filaments	indefinite	distinct	spiral	hypogynous	...	...	regular.
Anthers	2-lobed	distinct	...	...	...	...	...
Pistil	polycarpous	...	...	...	...	...	...
Carpels	indefinite	distinct, apocarpous.	spiral	...	...	...	regular.

Lamium (Dead-Nettle).

Organ.	Number.	Isolation.	Arrangement.	Insertion or Emergence.	Cohesion.	Adhesion.	Form.
Calyx	...	...	...	...	gamosepalous	...	irregular, bilabiate.
Sepals	5	...	verticillate	hypogynous	...	...	
Corolla	...	...	...	...	gamopetalous	...	irregular, bilabiate.
Petals	5	...	verticillate	hypogynous	...	...	
Stamens.							
Filaments	4	distinct	verticillate	perigynous	...	epipetalous	irregular, didynamous.
Anthers	2-lobed	...	...	...	...	...	
Pistil.							
Carpels	2	...	opposite	...	syncarpous	...	irregular.
Ovary	4-lobed	...	...	...	...	...	...
Styles	2	...	...	...	confluent	...	basilar.
Stigmas	2	distinct	...	...	...	...	...

Generic Character.—The *generic character* is perhaps the most important element in Systematic Botany. It should contain a short description of the peculiarities of the group, so as at once to characterize this as it exists in itself, and to furnish the means by which it may be distinguished from all other genera belonging to the same division of the Vegetable Kingdom. The following example of the character of the genus *Campanula*, Linn., as given in Endlicher's 'Genera Plantarum,' will illustrate this :—

"*Campanula*, Linn.—*Calyx* with an ovoid or subspherical tube adherent to the ovary, the limb superior, five-toothed; the teeth either flat at their margins or decurrent into lobes overlying the sinuses. *Corolla* inserted at the summit of the tube of the calyx, more or less campanulate, five-lobed or five-toothed at the apex. *Stamens* five, inserted with the corolla; filaments broadly membranaceous at the base, and, with the anthers, free. *Ovary* inferior, three- or five-celled; cells superposed to the lobes of the calyx. *Ovules* numerous, on placentas projecting from the central angles of the cell, anatropous. *Style* covered with quickly deciduous hairs; *stigmas* 3–5, filiform. *Capsule* ovate or turbinate, 3–5-celled; cells bursting near the top or bottom by a parietal valve turning upward. *Seeds* numerous, mostly ovate, flattened, more rarely ovoid and very small. *Embryo* orthotropous, in the axis of fleshy albumen; *cotyledons* very short; *radicle* next the hilum, centripetal.

"Perennial or annual herbs, sometimes low and tufted, sometimes erect, tall, many-flowered, diffused through all the temperate and cool regions of the northern hemisphere, forming a great ornament to meadows and groves; radical leaves very often larger and more obtuse, with longer stalks; stem-leaves alternate, varying; flowers mostly stalked, racemose, rarely spiked or in clusters, very often rather large, blue, or sometimes white in the same species."

The first paragraph here contains the *essential character* of the genus; the second paragraph is a description of the general characters of the species belonging to it, which is usually appended to such complete generic characters.

It will be observed that this generic character not only enables us to distinguish plants belonging to this group, but describes the genus so fully that we become acquainted with all its important peculiarities, while, being drawn up irrespectively of any Order, alliance, or class, it is equally available as material for any Natural or Artificial classification of Flowering plants founded on the floral organs, since it contains the information requisite for ascertaining its relations.

Diagnosis.—The *diagnosis* of a genus is more limited in its nature and purpose. It is used, when genera are described under fixed systematic heads simply for distinctive purposes; and it is therefore confined to denoting what is absolutely necessary for this purpose. Thus, in Babington's 'Manual of British Botany,' the genus *Campanula* occurs under the head of the Order Campanulaceæ, the character of which includes much of what is given in the generic

character of *Campanula*, above cited; so that it suffices for the distinction of *Campanula* from its allied genera to give the following brief abstract, or *diagnosis* :—

"*Campanula*:—*Calyx* 5-parted. *Cor.* mostly bell-shaped, *with 5 broad* and shallow segments. *Anthers* free; *filaments* dilated at the base. *Stigma* 3–5-fid. *Capsule* not elongated, 3–5-celled, opening by lateral pores outside the segments of the calyx."

It is seen at once that this *diagnosis* fails to furnish the complete notion of the genus which is obtained from the *descriptive character*, and that it does not suffice to indicate the position of the genus, either in a Natural or Artificial classification. On the other hand, for its own especial purpose (that is, of indicating the distinctions between allied genera), it may be even still more reduced, as is often done in works describing the plants of a limited district, where only a few genera occur in the natural order; for example, we might give diagnoses of the British genera of Campanulaceæ in this way—

A. Corolla rotate, segments linear; anthers cohering at the base. 1. *Jasione*.
Corolla rotate, with linear segments; anthers free. 2. *Phyteuma*.

B. Corolla mostly bell-shaped, with broad and shallow segments; anthers free.
Capsule not elongated, opening by lateral pores outside the segments of the calyx.................... 3. *Campanula*.
Capsule linear-oblong, prismatic, opening by lateral pores between the segments of the calyx .... 4. *Specularia*.
Capsule half-superior, opening by 3–5 valves within the segments of the calyx .... 5. *Wahlenbergia*.

Specific Character.—The *specific character* of a plant should mention all the constant distinctive peculiarities of a species. On the one hand, it should exclude the generic characters which ally it to other species of the same genus; on the other, it should exclude the inconstant characters which distinguish its own varieties. But the character of its ordinary varieties, if such exist, may be given in a supplementary paragraph, like that appended to the full generic character. The distinctive characters of species are usually found in the organs of vegetation, as the root, stem, leaves, bracts, and inflorescence, or in the habit or duration of the plant. The floral organs mostly only give specific characters in their less important peculiarities—as in the shape and relative magnitude of the petals, the external characters of the fruits and seeds, &c.—the more remarkable peculiarities being of generic value. The supplementary notices appended to the strict character of the species generally relate to the ordinary dimensions of the plant, the colour, taste, smell, &c. of its organs; these are the marks by which the *varieties* are usually characterized, as will be seen by referring to any catalogue of varieties of the ordinary cultivated vegetables.

The specific character will necessarily vary in length according to the richness of a genus in species, some containing many hundreds, while others comprise but a single one. When the genus contains but a single species, as the Hop (*Humulus Lupulus*), the generic character alone suffices for distinguishing it; but a specific character is even then given with advantage, indicating points which are not included in the strict generic character. Where a large number of species exist, the genus is generally broken up into artificial sections, characterized by some mark occurring regularly in a certain number, which are thus placed under one head: this saves the necessity of repeating that character for each species. It is also common in modern works to combine a diagnosis with the specific character, by marking in italics the especial distinctive marks of each species occurring in a particular group.

The following examples will make this more clear:—

Of *Syringa*, L., only six species are described in De Candolle's 'Prodromus,' being all that were known in 1844. The specific character of the common Lilac, *Syringa vulgaris*, could thus be given in a few words:—

"*S. vulgaris*, L. Leaves cordate or ovato-cordate, quite smooth and of even colour; limb of the corolla subconcave."

Four varieties are characterized, chiefly distinguished by the colours of the blossoms.

Turning to the genus *Campanula* in the same work, we find no less than 182 species. Being a very natural genus, the species are kept together under one generic name, but, for convenience, they are arranged in sections and subsections. Thus fifty-eight of them are characterized by the presence of appendages on the sinuses of the calyx, such as we find in the garden Canterbury Bell (*Campanula Medium*), while the remainder are without these. The second section, of 124 species (among which are included all our native kinds), is further divided into subsections, characterized principally by the peculiarities of the *capsule*, and these, again, into groups according to the kind of *inflorescence*, &c.; so that when we come to the specific character itself none of these points have to be repeated, and the definitions are restricted within very narrow limits, as for instance:—

"*C. rotundifolia*, L. Radical leaves stalked, cordate, rounded, crenato-dentate; stem-leaves linear or lanceolate; teeth of the calyx awl-shaped, erect, one-third the length of the bell-shaped corolla."

In a work devoted to a limited flora, as that of Britain, where there exist only eight species of *Campanula*, we may adopt the sectional divisions, and limit the specific character as above, or give a longer character, including the marks of the sections; the latter plan is the better, where space is not an object, since it makes the character itself more instructive. Thus, in the 'British Flora,' we find—

"*C. rotundifolia*, L. Glabrous; root-leaves subrotundo-cordate, crenate (very soon withering), lower cauline ones lanceolate, upper linear entire; flowers solitary or racemose, drooping; calyx-segments subulate; capsule drooping, with the clefts at the base."

In Babington's 'Manual,' on the contrary, where the subsections founded on the capsule are adopted, this mark is omitted in the essential character:—

"*C. rotundifolia*, L. *Radical leaves cordate or reniform*, shorter than their stalks; *stem-leaves linear*, the lower ones lanceolate; *flowers one or*

more, racemose; corolla turbinate-campanulate.—Stem 6–12 inches high. Radical leaves soon vanishing; corolla blue; calyx-segments linear-subulate."

This example further illustrates the method of giving a *diagnosis* at the same time, by *italicizing* the characters by which the species is distinguished from its nearest allies; it also shows the manner in which explanatory or descriptive notices are added in a supplementary paragraph to the essential specific character.

Lastly, if we have to deal with a limited number of species, such as the British Bell-flowers, to which we have just referred, we may, for simple purposes of distinction, construct a diagnostic table, like that above given for the genera of Campanulaceæ.

Flowers sessile, in terminal or axillary clusters; capsule sessile, erect, with the pores at the base . .	*C. glomerata.*
Flowers in racemes or panicles; capsule stalked.	
Capsule nodding, with the pores at the base.	
Flowers in a unilateral raceme, segments of calyx ultimately reflexed	*C. rapunculoides.*
Flowers racemose, segments of calyx always erect.	
Peduncles 1-flowered	*C. latifolia.*
Peduncles 2–3-flowered	*C. Trachelium.*
Flowers on long slender stalks, solitary, or in a lax few-flowered corymbose raceme . .	*C. rotundifolia.*
Capsule erect, with the pores just below the segments of the calyx.	
Segments of the calyx entire.	
Segments of the calyx lanceolate; raceme few-flowered, or flower solitary . .	*C. persicifolia.*
Segments of the calyx awl-shaped; flowers in an erect racemose panicle	*C. Rapunculus.*
Segments of the calyx toothed at the base; flowers panicled, erect, on long stalks .	*C. patula.*

A few of the general rules observed in writing descriptions of plants may be mentioned here, as explanatory of certain technicalities which will be met with in systematic works.

The generic name is always commenced with a capital letter, while that of the species is usually written small: but we find in most books a capital letter to the specific name, 1, where this name is the appellation of another existing or suppressed genus used adjectively, as *Agrimonia Eupatorium*, *Mentha Pulegium*, &c.; 2, where the specific name is formed from a proper name, either as the genitive case of a substantive or in the adjective form, as in *Scirpus Savii* and *Carex Davalliana*. Specific names derived from countries are now usually written small, as *Silene anglica*.

When a generic character is written in Latin, the descriptions of the organs are all put in the nominative case; in a specific character they are put in the ablative.

When describing a species, it is usual to subjoin its habitation (*Habitat*)—that is, the nature of the places in which it is usually found, such as "Woods," "Dry hilly places," "Rivers," &c. In general systematic works the native country or province is stated; in works relating to limited districts, special *localities* are given for rare plants.

The following marks and abbreviations are commonly in use to indicate certain other points:—

① or A =an annual plant.	♂, a male flower.
② or B =a biennial.	♀, a female flower.
♃ or P =a perennial.	⚥, an hermaphrodite flower.
Sh=a shrub.	♂ ♀, a monœcious plant.
T =a tree.	♂ - ♀, a diœcious plant.

The time of flowering is indicated by numbers, referring to the months, as 6–8 or vi–viii=June to August, &c. (See also p. 103.)

Many other signs are met with in Systematic works, but they are very often used in different senses by different authors, so that no general explanation of them can be given; moreover the sense in which they are used is generally explained by the author.

CHAPTER II.

SYSTEMS OF CLASSIFICATION.

Sect. 1. Artificial Classification of Plants.

An arrangement of all known species of plants in a series of classes, constituted upon certain fixed principles, forms what is termed a System of Vegetables.

The classification of plants by generalization, the Synthetic or Natural Method, is adopted in all cases in forming the groups of the lowest rank, namely *Genera*. These are established by the combination of a number of allied species under one name, on account of their affinities; and, as we have already mentioned, the same genera are used in all Classifications.

From this point Systems diverge. The *Natural Method* is pursued further on the same principles of generalization, where the object is to systematize acquired knowledge, mark the agreements and determine if possible the lineage of plants. Where, on

the other hand, it is chiefly desired to mark out the differences of plants, in order simply to their easy recognition, *Artificial Methods* are resorted to, which are carried out by a principle of *analysis*, whereby the whole mass of known forms is taken and gradually parcelled out into Classes, Orders, &c., according to their agreement or difference in certain fixed characters.

Most of the older systems were more or less Artificial, the earliest commencing with the division of plants into Trees, Shrubs, and Herbs, Land-plants and Water-plants, and the like. As advances were made, organs of more and more importance were chosen to furnish characters; and we find plants subsequently classed by their *corollas*, by their *fruits*, &c.; but in none of the systems proposed before the time of Linnæus do we find one given principle carried out through the whole.

The Linnæan System.—When Linnæus entered upon his labours, there lay before him a mass of information in a very unmanageable condition. His reforming genius introduced order, in the first instance, by the substitution of short fixed names for species, on the binomial plan, by the definition and secure establishment of imperfectly characterized genera and species, and then advanced to the necessary task of arranging the genera so as to render them recognizable. The artificial methods founded on the floral envelopes &c. had proved insufficient; and therefore he turned to the *essential organs* of flowers, the physiological importance of which he himself contributed greatly to establish. The selection of these organs resulted in the formation of an Artificial System in which a fixed principle is regularly carried out, and which, from the physiological importance of the characters employed, approaches in certain of its coordinations to a natural arrangement.

Species and *Genera* form the foundation of all Systems. The object of the Linnæan System was to arrange genera in groups characterized by simple striking marks, so that the existing description of a given plant might be readily found, or the description of a new plant might be placed where it would be easily referred to. Such marks Linnæus obtained in the *essential* or *sexual organs* of plants (in flowers, the *stamens* and *pistils*), whence his System is sometimes called the Sexual System. The highest or most general groups, which he called *Classes*, are founded on the conditions of the *stamens*. These Classes are subdivided into *Orders*, founded either on the conditions of the *pistils* or upon *secondary characters of the stamens*. The orders include the *Genera* (in large Orders grouped into sections according to various artificial characters). The Linnæan *Classes* are twenty-four in number, of which the first twenty-three include all Flowering Plants: the

twenty-fourth, Cryptogamia, including all Flowerless Plants, was a *chaos* when first established, and its subdivisions were not then definable by single characters. As the Linnæan system is no longer in use, further mention of it is not needed.

Sect. 2. Natural Classification of Plants.

In this method of classifying we pursue the same path by which we arrived at the genera, and combine these into more general groups, not according to arbitrarily chosen or isolated characters, but according to their natural affinities—that is, the agreement in their total organization, and consequently their presumed degree of kinship. Genera are thus gathered together into *Families* or *Orders*, these into *Cohorts* and *Classes*, and finally the entire Vegetable Kingdom becomes marshalled into a few *Provinces* or *Subkingdoms*.

It is evident from this, that a Natural System founded on a perfect knowledge of all existing plants would present to us a kind of abstract picture of the Vegetable Kingdom, in which all its essential characters would be represented in their real proportions, places, and connexion. Not only, however, are we far from being acquainted with all existing plants (not to mention the numerous kinds now extinct), but the essential peculiarities of a vast number of the known plants have been as yet but imperfectly studied. Hence we have at present various plans for the Natural Arrangement of plants, presenting peculiarities dependent upon the amount of knowledge, or the peculiar views, of their respective authors; which plans or Systems must be regarded as so many rough draughts or sketches, to serve as material for the elaboration of the true and complete Natural System. As the principles of classification are fully recognized, and as the amount of plants thoroughly known is already very large, there is a close agreement in the general features of the different "Natural Systems," and especially in the manner in which the Orders of plants are defined. The chief diversities of opinion arise out of the different estimations of affinities and differences of the families.

Value of Characters.—To characterize the Natural Method more distinctly, it must be added that especial attention is paid to the relative importance of the characters presented by each plant, a determinate scale being formed, in which the organs are ranked according to their "congenital" or "acquired" origin, their physiological importance, the complexity of their construction, and their comparative invariability. Congenital characters are common to the largest number, and are the most constant, hence the most important.

Thus, while species of the same genus, distinguished generally by the external characters of their vegetative organs, are combined by likeness in their flowers, genera (in which difference of the floral envelopes, or of the external character of the fruit, or some such character exists) are

combined into an Order on account of the agreement in the structure of the ovary and its relations to the floral envelopes. The characters of seeds, and more particularly of the embryos, give a still higher divisional character. These characters of successively higher groups are marked in organs of progressively higher physiological and morphological importance, affinities between such organs being proportionately more valuable. But they possess this value not merely on their own account; for if that were the case, the method would be still to a great extent artificial: they indicate the coexistence of proportionate agreement in the total organization, which renders them exponents not merely of the affinities of the plants in respect to the particular structure to which they belong, but of all their affinities, and of the rank which a given plant holds in the Vegetable Kingdom. As a general rule, it is found that the agreement of the total organization of plants is generally proportionate to the physiological value of any given organs in which they agree; or, in other words, agreement in the structure of any given organ indicates general agreement in all the organs of less importance than itself. The agreement here referred to is of course a general structural agreement, a relation to a common type—not a resemblance excluding the multifold minor diversities which present themselves within the limits of almost every type.

Practically, moreover, we have another principle to keep in view, which indeed, while it affords as it were the verification of the inductions of the above principle, is our sole guide in dealing with the subdivisions of the more comprehensive types. This is the rule that the closest affinities are marked by the agreement in the majority of characters of *equal* importance; or if the characters, as is more commonly the case, are of unequal importance, the principle of decision by the majority is carried out by ascertaining the proportionate values of the organs in which agreements and differences exist, and striking a balance as with equal factors.

Many of the older botanists had attempted to construct a Natural System; and Linnæus left a sketch or fragment of one, in the form of a list of names of families without definitions, regarding its realization as the ultimate aim of Botany. Many of the families in these older Systems are grounded almost exclusively on "habit," or general external character. The two Jussieus, Bernard and Antoine-Laurent, have the merit of the discovery of the only principles upon which a really Natural System can be founded. And so accurately did A.-L. de Jussieu carry out these principles in his arrangement of the then existing genera, that the families which he established are still almost all received into our present Systems, where some of them are indeed broken up into smaller groups, but where the greatest increase in the number of families arises from subsequent discoveries.

The characters of the natural Families established in this way will be found to be far less exact and definite than those of the Linnæan classes and orders, and by no means so rigid even as those of natural genera. The character of a family is founded on the *totality* of its essential characters, and includes the essential characters of agreement of all its genera. The genera contained in most of the families exhibit a considerable range of differences;

allowance must be made for these; and this gives a laxity to the family character which is puzzling to the beginner. For example, the family Ranunculaceæ is very natural; but we find in its character a certain range of difference allowed for in the sepals, petals, pistils, and fruit; the insertion of all these, however, and that of the stamens, is fixed, and so is the character of the seed. Similar conditions occur in most other families. The decision as to what family a genus is to be referred to is made according to the principle of majorities: whichever it agrees with in *most* of its characters (say, even three out of five), to that family it belongs. Great difficulty, however, exists in certain cases from a vast series of genera running into one another by almost imperceptible gradations, and this in different directions. A considerable number of these agreeing closely are associated into a family; another similar group forms another family, and so on; and then, in the course of time, sundry intermediate genera present themselves, which connect the established families, and which it is difficult to place by the usual choice in either one or the other, the characters being balanced. Thus the Natural family Loganiaceæ is connected by "aberrant" genera with Rubiaceæ, Gentianaceæ, Scrophulariaceæ, and other families which are truly natural, but which in this way come to be separated by somewhat indefinite boundary-lines. The fact is, that the Vegetable Kingdom is a whole, the families having seldom a distinct isolated existence, except in the minds of botanists. It may be presumed that they are all variations from one or a few original stocks, and thus have numerous intermediate or connecting links; and we must regard them as analogous to countries on the globe, which are parcelled out under distinct names, but most often adjoin and run into one another, being only separated by an arbitrary boundary-line. Some, indeed, lie off from the rest, like islands, the intervening links being extinct; but these are the exceptions. Such exceptions are found among the families which were established by the older botanists, in which the essential agreements are accompanied by a striking character of external habit, as in the Grasses, the Umbelliferæ, the Compositæ, the Leguminosæ, the Coniferæ, the Palms, &c. Such remarkable peculiarities as these families possess mostly prevent them being broken up into smaller groups, as has occurred to many of the earlier orders of large extent; and most botanists prefer to distribute these genera into *suborders* rather than discard the characteristic general name. Examples of these are found especially in the Leguminosæ, Rosaceæ, and Compositæ.

The Families or Orders are for the most part the same, in all essential respects, in all existing "Natural Systems." A considerable diversity presents itself in the modes in which different authors have grouped these into *Classes* or *Alliances*. These, however, are still Natural groups, as are also those of still higher generality indicated in the chapter on General Morphology. But all writers on Systematic Botany have found it requisite to group the Orders or Classes of Flowering Plants into sections of somewhat less generality than Dicotyledons and Monocotyledons, as these respectively include series of families so extensive as to be inconvenient in practice if left undivided. The members of these series, however, are so intimately connected together by their natural

affinities, that it has been found indispensable to have recourse to certain arbitrary or artificial characters for the foundation of the sections—characters derived chiefly from the conditions of the petals and stamens. The nature of these Sections will be best understood from the examples which follow.

The Jussieuan System.—Jussieu established his primary divisions of the Vegetable Kingdom on characters which, although not unexceptionable, define really natural groups, which are found under different titles in all Natural Systems. The characters were the absence or presence of the embryo, and its structure when present, in the seed. On these characters stood the three divisions *Acotyledons* (plants without an embryo), *Monocotyledons*, and *Dicotyledons*. The first of these names is bad, as founded upon a *negative* character; but the plants which it included were imperfectly understood in the time of Jussieu; the Acotyledons correspond to the Cryptogamia of Linnæus, which are now by more complete analysis distributed into two sections, divided by even more important characters than the Monocotyledons and Dicotyledons. The other two divisions are still retained, with very slight modifications, in all Systems, but are subordinated under divisions founded on more important characters.

The following Table exhibits Jussieu's arrangement:—

				Class
Acotyledons				I.
Monocotyledons		Stamens hypogynous		II.
		,, perigynous		III.
		,, epigynous		IV.
Dicotyledons	APETALOUS	Stamens epigynous		V.
		,, perigynous		VI.
		,, hypogynous		VII.
	MONOPETALOUS	Corolla hypogynous		VIII.
		,, perigynous		IX.
		,, epigynous	Anthers coherent	X.
			Anthers distinct	XI.
	POLYPETALOUS	Stamens epigynous		XII.
		,, hypogynous		XIII.
		,, perigynous		XIV.
	DICLINOUS, irregular			XV.

The three primary divisions here are natural; the Classes must be regarded as artificial; the Families, however, into which the latter are divided, are natural groups, and to a great extent are retained in more modern systems. The families of Jussieu were more carefully defined, corrected, and extended by Robert Brown, whose researches contributed most essentially to the establishment of the Natural System; but he did not attempt to establish any general plan for their coordination in Classes.

De Candolle's System.—Aug. Pyrame De Candolle endeavoured to classify the Vegetable Kingdom on principles more in harmony with the knowledge of the structure of plants accumulated since the promulgation of Jussieu's System. De Candolle's System has become very generally used, on account of its having been adopted in the great Descriptive work which he commenced, the 'Prodromus Systematis Naturalis Regni Vegetabilis,' a description of all known species of plants. His subdivisions of the Exogens (or more properly Dicotyledons) are retained in many works. They are artificial, like the "Classes" of Jussieu, but are, like them, convenient for the distribution of the families into groups of manageable dimensions. They are four in number, and founded on characters of the floral envelopes, viz.:—1. THALAMIFLORÆ, in which the petals are distinct and (like the stamens) inserted on the receptacle (hypogynous); 2. CALYCIFLORÆ, with the petals distinct or coherent and (with the stamens) inserted on the calyx (perigynous); 3. COROLLIFLORÆ, with the petals coherent, and inserted on the receptacle (the stamens being inserted on the corolla); and, 4. MONOCHLAMYDEÆ, or plants with a perianth or a single circle of envelopes.

In De Candolle's enumeration of the families, which had greatly increased in number from Jussieu's list, the reverse order of sequence is followed, the higher plants standing first. As regards this point, however, it is a misconception to place the *Thalamifloræ* first among the Dicotyledons, since they are manifestly inferior to the *Calycifloræ*, and even to the *Corollifloræ*.

During the last forty years a great many attempts have been made to distribute the Orders more satisfactorily into Classes and primary Divisions. Endlicher, Bartling, Meisner, Brongniart, Lindley, and many other authors have published Systems of their own.

Endlicher's System.—That of Endlicher has been extensively used, and, moreover, is the basis of arrangement in his great 'Genera Plantarum.'

Region 1. **Thallophyta.** Sect. I. PROTOPHYTA; II. HYSTEROPHYTA.

Region 2. **Cormophyta.**

Sect. III. ACROBRYA. *Cohort* 1. Acrobrya anophyta; 2. Acrobrya protophyta; 3. Acrobrya hysterophyta.

Sect. IV. AMPHIBRYA. V. ACRAMPHIBRYA. *Cohort* 1. Gymnospermeæ; 2. Apetalæ; 3. Gamopetalæ; 4. Dialypetalæ.

The cohorts are subdivided into classes, and these again into orders.

Brongniart's System.—The arrangement of Brongniart is much followed in France. Its general character may be understood from the following table:—

Division I. **Cryptogamæ.** Branch 1. AMPHIGENÆ (Thallogens); Branch 2. ACROGENÆ.

Division II. **Phanerogamæ.**

Branch 3. MONOCOTYLEDONES. Series 1. Albuminosæ; 2. Exalbuminosæ.

Branch 4. DICOTYLEDONES.

Subbranch 1. *Angiospermæ.* Series 1. Gamopetalæ: § i. Perigynæ; § ii. Hypogynæ. Series 2. Dialypetalæ: § i. Hypogynæ; § ii. Perigynæ.

Subbranch 2. *Gymnospermæ.*

Lindley's System is the one proposed by its distinguished author in his 'Vegetable Kingdom.' Although the system itself was never generally adopted, the book itself is an admirable encyclopædia on all points relating to Systematic Botany and the uses of plants up to the date of publication. Lindley's main groups were:—I. THALLOGENS; II. ACROGENS; III. RHIZOGENS; IV. ENDOGENS; V. DICTYOGENS; VI. GYMNOGENS; VII. EXOGENS; the latter being subdivided into Diclinous, Hypogynous, Perigynous, and Epigynous subclasses. The subclasses were again divided into alliances, and these into orders. The special peculiarity of this system is the formation of a group for certain root-parasites, destitute of true leaves; and of Dictyogens—a class of plants with the netted venation of Exogens and the ternary flowers of Endogens.

Bentham and Hooker's System.—Since the publication of the 'Vegetable Kingdom' a very important work on Systematic Botany has been commenced by Mr. Bentham and Sir Joseph Hooker, entitled 'Genera Plantarum.' This work, so far as at present published, comprises a description, in Latin, of all the known genera of Polypetalous and Gamopetalous Exogens, together with analytical tables admitting of the ready determination of any particular genus, notes of aberrant or exceptional forms, &c. Their scheme is more fully explained in the English translation of Le Maout and Decaisne's 'General System of Botany,' edited by Sir Joseph Hooker. Its main features are given in the following table. The arrangement of the Monocotyledons, however, is taken from Mr. Bentham's paper on the classification of Monocotyledons, in the 'Journal of the Linnean Society' for November 1876.

Subkingdom I. **PHANEROGAMIA.**

Class I. **Dicotyledones.** Subclass I. ANGIOSPERMEÆ. Division 1. *Polypetalæ.* Series 1. Thalamifloræ; 2. Discifloræ; 3. Calycifloræ.—Division II. *Monopetalæ.* Series 1. Epigynæ; 2. Hypogynæ v. Perigynæ.—Division III. *Apetalæ.* Series 1. Hypogynæ; 2. Epigynæ v. Perigynæ.—Subclass II. GYMNOSPERMEÆ.

Class II. **Monocotyledones.** Series 1. Epigynæ; 2. Coronariæ; 3. Nudifloræ; 4. Glumales.

Subkingdom II. **CRYPTOGAMIA.**

Class III. **Acrogens.**

Class IV. **Thallogens.**

Subordinate to the "series" are "cohorts," or groups of orders of equal value, though with different limitations, to the "alliances" in Lindley's 'System.' The only point which requires explanation here is the series *Discifloræ*, which includes those polypetalous hypogynous orders in which there is a conspicuous hypogynous disk or series of glands, into or between which the stamens are inserted.

Braun's System.—In Germany the classification of A. Braun is now much followed. The following are his main groups of Phanegams as modified by Hanstein, Sachs, and others:—

DICOTYLEDONES.

Julifloræ.	**Monochlamydeæ.**	**Aphanocyclæ.**	**Tetracyclæ.**	**Perigynæ.**
Piperineæ.	Serpentarieæ.	Hydropeltidineæ.	*a. Gamopetalæ.*	Calycifloræ.
Urticineæ.	Rhizantheæ.	Polycarpæ.	Anisocarpæ.	Corollifloræ.
Amentiferæ.		Crucifloræ.	Isocarpæ.	
			β. Eleutheropetalæ.	
			Eucyclæ.	
			Centrospermæ.	
			Discophoræ.	

Julifloræ correspond nearly to Amentales, and are characterized by spicate or amentaceous inflorescence, diclinous flowers, and mono- or achlamydeous flowers. Monochlamydeæ have a well-marked perianth of one row; Aphanocyclæ have calyx and corolla, the parts of the flower (except in some cases the carpels) being arranged in spiral cycles. In Tetracyclæ, the parts of the flower are in whorls. This group comprises

the Thalamifloral, Calycifloral, and Corollifloral divisions of De Candolle. Perigynæ: perianth tubular below, bearing the stamens, and free from or adherent to the carpels. In this group the Calycifloræ have a single perianth, the Corollifloræ a calyx and corolla.

Classification of Cryptogams.—This is in a transitional state. The following is the latest arrangement, adopted by Sachs. It will be seen that the orders are arranged in two parallel series, according to the presence or absence of chlorophyll.

Group I. **Thallophyta.**

Class 1. Protophyta.

With chlorophyll.	Without chlorophyll.
Cyanophyceæ.	*Schizomycetes.*
Chroococcaceæ.	Sphærobacteria.
Oscillatorieæ.	Microbacteria.
Scytonemeæ.	Desmobacteria.
Nostocaceæ.	Spirobacteria.
Rivulariaceæ.	
Palmellaceæ.	
Euglenæ.	*Saccharomyces.*

Class 2. Zygosporeæ.

A. *Conjugating cells motile.*

Volvocineæ.	*Myxomycetes.*
[*Hydrodictyeæ.*]	
Confervaceæ.	
Ulvaceæ.	

B. *Conjugating cells stationary.*

Conjugatæ.	*Zygomycetes.*
Desmidieæ.	Mucorini.
Diatomaceæ.	Piptocephalidæ.
Mesocarpeæ.	
Zygnemeæ.	

Class 3. Oosporeæ.

Sphæroplea.

Cœloblastæ.

Vaucheria .... { Saprolegnieæ. Peronosporeæ. }

Œdogonieæ.

Fucaceæ.

[*Phæosporeæ.*]

Class 4. Carposporeæ.

With chlorophyll.	Without chlorophyll.
Coleochætæ.	*Ascomycetes.*
	Gymnoascus.
Florideæ.	Discomycetes.
Nemalieæ.	Erysipheæ.
Ceramieæ.	Tuberaceæ.
Dudresnaya.	Pyrenomycetes.
	Lichenes?
Characeæ.	*Æcidiomycetes.*
	Basidiomycetes.
	Exobasidium.
	Tremellini.
	Hymenomycetes.
	Gasteromycetes.

Group II. **Cormophyta.**

Series I. BRYOPHYTA.

Class 1. Musci.

Class 2. Hepaticæ.

Series II. PTERIDOPHYTA.

Class 1. Filicales.

i. *Stipulatæ.*

Ophioglosseæ.

Marattiaceæ.

ii. *Filices.*

iii. *Rhizocarpeæ.*

Class 2. Equisetaceæ.

Class 3. Dichotomæ.

i. *Lycopodiaceæ.*

Lycopodieæ.

Psiloteæ.

Phylloglosseæ.

ii. *Ligulatæ.*

Selaginelleæ.

Isoeteæ.

Caruel's System.—Quite recently an arrangement has been proposed by Professor Caruel, based on the circumstance that there are in the same individual plants sexual forms or stages, male or female as the case may be, and an asexual or neutral form; thus in Phanerogams the asexual form is the embryo developing indefinitely and becoming ultimately an adult plant, which latter produces a male form, the pollen, and a female form, the ovule, which becomes a seed with definite evolution, containing "oospheres" or germinal vesicles in a closed "oogonium" or embryo-sac. The following are the outlines of the scheme, which we give in this place, though

it cannot be understood by the pupil until after he has made himself acquainted with the morphology and physiology of Cryptogams and Phanerogams and the details of the reproductive process in the several orders.

Caruel's primary groups are:—

I. PHANEROGAMÆ.—Plants trimorphic, one form neutral, producing agamically two sexual forms, male and female respectively; neutral form originating from a fertilized oosphere and developing into a pro-embryo, like the embryo originating longitudinally; evolution indefinite. Male form represented by the pollen in the anther. Female by the ovule, ultimately the seed: evolution definite, containing the oospheres in a closed oogonium.

II. SCHISTOGAMÆ.—Plants trimorphic. Neutral form originating from a fertilized oosphere, developing, like the embryo, transversely: evolution indefinite. Male form a vermiform phytozoon (spiral spermatozoid) formed within an antherocyst. Female form an oogemma, then a seminulum, with definite evolution, containing an oosphere in an open oogonium. (Characeæ.)

III. PROTHALLOGAMÆ.—Plants trimorphic. Neutral form produced from a fertilized oosphere, developing, like the embryo, transversely: evolution indefinite. Male form a vermiform phytozoon formed within an antheridium. Female form a spore, developing into a prothallus: evolution definite, containing a naked oosphere within an archegonium. (Vascular Cryptogams.)

IV. BRYOGAMÆ.—Plants trimorphic. Neutral form originating from a fertilized oosphere, developing, like the embryo, longitudinally: evolution definite. Male form a vermiform phytozoon from an antheridium. Female form a spore developing into a thallus or "cormus:" evolution indefinite, and containing a naked oosphere in an archegonium. (Muscineæ.)

V. GYMNOGAMÆ.—Plants di-, trimorphic. In the trimorphic form the neutral form is an oospore arising directly from a fertilized oosphere: evolution indefinite. Male form a zoosporiform phytozoon from an antheridium. Female form a spore developing into a thallus: evolution indefinite, containing an oosphere in a naked open oögonium. In the dimorphic plants, two sexual forms only, the male a phytozoon or pollinidium. In the monomorphic plants a single form without sexual distinction: evolution definite or indefinite. (Cellular Cryptogams.)

In the following pages the arrangement adopted is, for Dicotyledons mainly that of De Candolle, for Monocotyledons that of Bentham.

VEGETABLE KINGDOM.

Subkingdom I. **PHANEROGAMIA.** (*Flowering Plants.*)

Class I. DICOTYLEDONES. (*Exogens.*)

Subclass i. *ANGIOSPERMIA.*

Division 1. **Polypetalæ.**

Series 1. THALAMIFLORÆ.

" 2. CALYCIFLORÆ.

Division 2. **Gamopetalæ** or **Corollifloræ.**

Series 1. INFERÆ or EPIGYNÆ.

" 2. SUPERÆ.

" 3. DICARPIÆ.

Division 3. **Apetalæ** or **Incompletæ.**

Series 1. SUPERÆ.

" 2. INFERÆ or EPIGYNÆ.

Subclass ii. *GYMNOSPERMIA.*

Class II. MONOCOTYLEDONES. (*Endogens.*)

Division 1. **Petaloideæ.**

Series 1. EPIGYNÆ.

" 2. CORONARIEÆ.

A. Syncarpiæ.

B. Apocarpiæ.

Division 2. **Spadicifloræ.**

" 3. **Glumifloræ.**

Subkingdom II. **CRYPTOGAMIA.** (*Flowerless Plants.*)

Class I. CORMOPHYTA. (*Acrogens.*)

Division 1. **Vascularia.**

Series 1. ISOSPORIA.

" 2. HETEROSPORIA.

Division 2. **Muscineæ.**

Class II. THALLOPHYTA. (*Thallogens.*)

Division 1. **Algæ.**

" 2. **Fungi.**

In the following systematic description of the Natural Orders, the characters of the most important are given at length, with the necessary particulars respecting their affinities, geographical distribution, and the qualities of the more important plants they contain. To most is prefixed a short diagnosis; and a similar diagnosis, or a few explanatory remarks,

printed in smaller type, are accorded to those Orders which either are not marked by very decided characters, or which do not demand so much attention from the beginner. In most cases the views of other botanists as to the position and limitation of the groups are briefly mentioned. Under each Order are placed the names of one or more genera which furnish good illustrations and which are generally accessible for practical examination.

CHAPTER III.

SYSTEMATIC DESCRIPTION OF THE NATURAL ORDERS.

THE VEGETABLE KINGDOM.

SUBKINGDOM I. PHANEROGAMIA, or FLOWERING PLANTS.

Plants producing stamens and pistils in association or separately, and forming seeds containing an embryo.

CLASS I. DICOTYLEDONES.

Flowering Plants, with stems (when woody) having pith and bark separated by a compact layer of wood, which, in perennial plants, receives annual additions on the outside, beneath the bark; leaves with the ribs mostly distributed in a netted pattern and generally diminishing in size as they branch; parts of the floral circles mostly 5 or 4, or some multiple of those numbers, rarely 3; embryo with a pair of cotyledons and a radicle, which is developed into a tap-root in germination. The typically complete floral formula, supposing the parts to be uncomplicated by adhesions, irregular growth, multiplication, &c., is S5 P5 A5 G5, in regular alternation.

SUBCLASS I. *ANGIOSPERMIA.*

Flowering Plants, with the ovules formed in closed ovaries. Endosperm formed after fertilization. Pollen-cells not dividing prior to the emission of pollen-tubes (*see* under "Reproduction").

Division I. **Polypetalæ.**

Petals distinct, rarely absent or united.

Exceptions.—Hooker notes the following exceptions. Apetalous flowers occur in some species of Menispermaceæ, Caryophyllaceæ, Malvaceæ, Sterculiaceæ, Tiliaceæ, Rutaceæ, Simarubaceæ, Burseraceæ, Olacaceæ, Celastraceæ, Saxifragaceæ, Crassulaceæ, Myrtaceæ, Passifloraceæ. Apetalous flowers also may be met with in some Ranunculaceæ, Magnoliaceæ, Berberidaceæ, Sarraceniaceæ, Papaveraceæ, Cruciferæ, Canellaceæ,

Fig. 330.

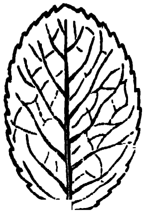


Fig. 332.

Fig. 331.

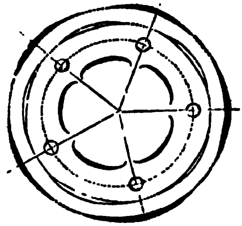


Fig. 333.

Fig. 330. Netted-veined leaf of a Dicotyledon.
Fig. 331. Quinary plan of the flower, the parts regularly alternating.
Figs. 332 & 333. Dicotyledonous embryos.

Fig. 334.

Fig. 335.

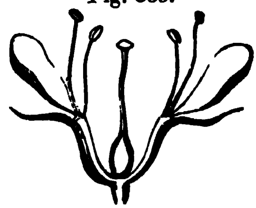


Fig. 336.

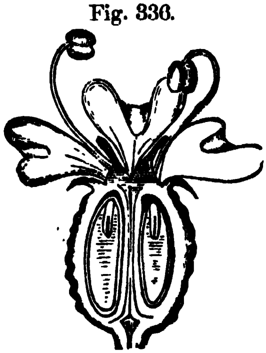
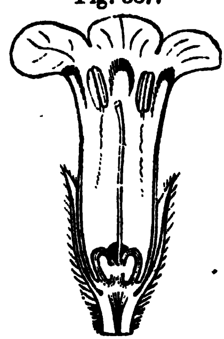


Fig. 338.

Fig. 337.



Figs. 334–338 are illustrative of the Subclasses of Dicotyledons.

Fig. 334. Thalamifloræ (*Ranunculus*).
Fig. 335. Calycifloræ, perigynous (*Prunus*).
Fig. 336. Calycifloræ, epigynous (*Fœniculum*).
Fig. 337. Corollifloræ (*Symphytum*).
Fig. 338. Incompletæ (Monochlamydeæ) (*Ulmus*).

Bixaceæ, Violaceæ, Zygophyllaceæ, Geraniaceæ, Rhamnaceæ, Sapindaceæ, Terebinthaceæ, Rosaceæ, Hamamelidaceæ, Balsamifloræ, Haloragaceæ, Gunneraceæ, Callitrichaceæ, Rhizophoraceæ, Combretaceæ, Lythraceæ, Onagraceæ, Samydaceæ, Loasaceæ, Datiscaceæ, Ficoideæ, Tetragoniaceæ, Cornaceæ, and Garryaceæ.

Plants with connate petals occur in the following usually polypetalous orders:—Anonaceæ, Pittosporaceæ, Polygalaceæ, Portulacaceæ, Tamariscaceæ, Ternstrœmiaceæ, Dipterocarpaceæ, Humiriaceæ, Diosmeæ, Balsaminaceæ, Meliaceæ, Stackhousiaceæ, Droseraceæ, Bruniaceæ, Napoleoneæ, Melastomaceæ, Turneraceæ, Cucurbitaceæ, Cactaceæ, etc.

Series I. THALAMIFLORÆ.

Calyx, corolla, and stamens usually free and springing directly from the thalamus, or from the outside of an hypogynous disk.

Exceptions.—The following are noted by Hooker. Connate sepals occur in a few orders. The calyx is adnate to the ovary, or to a fleshy thalamus in *Pæonia* (Ranunculaceæ), Calycanthaceæ, some Anonaceæ, Nymphæaceæ, Portulacaceæ. Capparidaceæ, Bixaceæ, Polygalaceæ, Ternstrœmiaceæ, Vochysiaceæ, Tiliaceæ, and Dipterocarpaceæ. The stamens are perigynous in some Dilleniaceæ, Papaveraceæ, Capparidaceæ, Moringaceæ, Resedaceæ, Violaceæ, Caryophyllaceæ, Portulacaceæ, Malvaceæ, and Sterculiaceæ.

ORDER RANUNCULACEÆ. THE CROWFOOT ORDER.

Cohort. Ranales, *Benth. et Hook.*

Diagnosis.—Herbs, or climbing shrubs, with a colourless acrid juice; leaves alternate, rarely opposite, simple or deeply divided; leaf-stalks often sheathing at the base; flowers regular or irregular,

Fig. 340.

Fig. 339.

Fig. 341.

Fig. 339. Achene of *Ranunculus*, cut vertically to show the seed, with an embryo at the base of perisperm.
Fig. 340. Flower of Aconite, side view, showing the irregular petaloid calyx.
Fig. 341. The same, with the sepals removed, showing the singularly formed petals and the numerous hypogynous stamens.

polypetalous or occasionally apetalous, with the calyx petaloid; the sepals, petals, and numerous stamens all distinct and hypogynous;

carpels many or few (rarely solitary), all distinct; seed perispermic; embryo small.

Character.

Thalamus convex or flat, often elongated, very rarely concave. *Calyx* green or petaloid, regular or irregular (fig. 340); *sepals* 3–6, hypogynous, deciduous, occasionally persistent, usually imbricated in æstivation, sometimes valvate or induplicate. *Corolla*: *petals* 13–15, distinct, hypogynous, in one or more rows, sometimes deformed (fig. 341) or wanting. *Stamens* indefinite, or very rarely definite, hypogynous; *anthers* adnate, bursting longitudinally. *Ovaries* several or few, simple, 1-celled, distinct, or very rarely coherent below to form a compound many-celled ovary; *styles* simple; *cells* 1- or many-seeded; *placentas* at the ventral sutures; *ovules* anatropous. *Fruit*: a collection of dry achenes, a 1- or few-seeded berry, or a circle of follicles more or less coherent below, bursting at the ventral suture; *seeds* solitary, erect or pendulous, or rarely horizontal in two rows; *embryo* straight, minute, in the base or within the apex of horny *perisperm* (fig. 339).

ILLUSTRATIVE GENERA.

Tribe 1. CLEMATIDEÆ. *Mostly climbing plants with opposite leaves. Calyx valvate or induplicate; fruit of achenes, usually surmounted by the persistent and plumose style.*

Clematis, *L.*

Tribe 2. ANEMONEÆ. *Calyx usually coloured, imbricated; achenes sometimes tailed; seed inverted.*

Thalictrum, *Tournef.*
Anemone, *Haller.*
Adonis, *DC.*

Tribe 3. RANUNCULEÆ. *Calyx imbricated; achenes not tailed; seed erect.*

Ranunculus, *L.*

Tribe 4. HELLEBOREÆ. *Calyx imbricated; petals irregular or none; fruit of many-seeded follicles, more or less coherent, rarely baccate.*

Caltha, *L.*
Helleborus, *Adans.*
Nigella, *Tournef.*
Aquilegia, *Tournef.*
Delphinium, *Tournef.*
Aconitum, *Tournef.*
Actæa, *L.*

Tribe 5. PÆONIEÆ. *Calyx imbricated; petals flat or none; carpels forming dehiscent pods, surrounded at the base by a disk.*

Pæonia, *Tournef.*

Affinities and Morphological Structure.—The typical floral formula is S 5 P 5 $\sim$ A∞ $\sim$ G ∞, the $\sim$ indicating a spiral arrangement, with vaiations, arising from suppression, multiplication, irregular growth, &c. The characters which are almost universally found are the free sepals and petals, the indefinite stamens, the inverted ovules, and the presence of perisperm. None of these, taken separately, are absolutely characteristic of the order, though collectively they are of the greatest importance. The other characters are all more or less inconstant or variable, some of the genera possessing them, others not. The conditions of the calyx and corolla, and also of the ripe fruit, are not only normally very varied in the different genera, but are readily affected and altered by cultivation.

The affinities of the Order are somewhat complex: the structure of the essential organs allies them closely to the Magnoliaceæ and Dilleniaceæ, the former of which, however, have distinct stipules, while the latter have arillate seeds; and both differ in habit. Some genera are closely related to the Berberidaceæ, from which, however, they differ in the indefinite stamens and in the sutural (not valvular) dehiscence of the anthers. From Nymphæaceæ and Papaveraceæ, which they resemble in certain respects, they are distinguished by their distinct carpels, and in the case of the Poppies by their watery (not milky) juice. Relations exist also with some Calycifloræ, as with Rosaceæ, from which the present Order is known by its hypogynous stamens, the abundant perisperm of the seeds, and the general properties. Sheathing bases of the leaves, resembling adnate stipules, occur here and in Umbelliferæ, and they somewhat resemble the stipules of *Rosa*. A kind of representation of this Order occurs among the Monocotyledons, in Alismaceæ, where the free carpels and the habit give a resemblance to those Ranunculaceæ which have a ternary calyx. The Pæonies approach the Nymphæaceæ in the disk, which is remarkably developed in *P. Moutan*, almost entirely enclosing the carpels; the stamens of Pæonies are, owing to a slight excavation of the receptacle, perigynous rather than hypogynous.

Fig. 342.

Aconitum Napellus.

Number and Distribution.—This Order contains from 30 to 40 genera and five or six hundred species, which latter are most abundant in damp, cool climates, and are scarcely met with in the tropics, except on mountains.

Qualities and Uses.—The plants of this Order generally possess acrid and more or less narcotic-acrid properties, some being virulent poisons. The poisonous property resides in the watery juice, and is in most cases volatile, and capable of dissipation by heat, or even simple drying, and by infusion in water. It appears to be

heightened in power by acids, spirits, sugar, &c. The species of *Ranunculus* (Crowfoots or Buttercups) are acrid when fresh, especially *R. sceleratus* and *R. Flammula.* Similar properties prevail in the tribes *Clematideæ* and *Anemoneæ.* The *Helleboreæ* are the most active of the Ranunculaceæ, the species of *Aconitum* (Monkshood) being among the most dangerous of poisonous plants, and containing an extremely powerful alkaloid, *aconitina.* The species of this genus appear to differ in the quality of their juices when grown under varied conditions, somewhat like the Hemp-plant, since the roots of the most poisonous of them are said to be eaten with impunity in the higher parts of the Himalayas. *A. Napellus* (fig. 342) and *A. Cammarum* (*paniculatum*) are well-known poisonous European Monkshoods; and, according to Dr. Hooker, the celebrated "Bikh" poison of India is obtained indiscriminately from *A. Napellus, luridum,* and *palmatum,* as well as from *A. ferox,* L., which was supposed to be the sole source. The yellow *A. Lycoctonum* of Central Europe is far less active. The seeds of *Delphinium Staphisagria* (Stavesacre) are drastic purgatives and emetics; the Hellebores (*Helleborus niger, orientalis,* and *fœtida* especially) are likewise violent evacuants, and the Pæonies fall into the same category. The berries of the *Acteæ* are poisonous. Some of the milder plants are used as tonics, on account of the powerful bitter they contain, as the Yellow-root (*Hydrastis canadensis*) and the Gold-thread (*Coptis trifoliata*), both North-American plants. The pungent seeds of *Nigella sativa* were formerly used as pepper. The root of *Actæa racemosa* is used medicinally under the name *Radix Cimicifugæ.*

Many of the Ranunculaceæ are favourite garden plants: for example the species of *Clematis, Anemone, Ranunculus, Eranthis* (Winter Aconite), *Helleborus, Nigella, Aquilegia* (Columbines), *Delphinium* (Larkspurs), *Aconitum* (Monkshood), and *Pæonia.*

DILLENIACEÆ are trees or shrubs mostly with alternate leathery feather-veined leaves, generally destitute of stipules; an imbricated 5-merous calyx and corolla (the former persistent); numerous hypogynous stamens; solitary, few, or numerous, distinct or rarely coherent carpels; seeds several, 2, or 1 by abortion, arillate; perisperm fleshy.—Illustrative Genera: *Dillenia,* L.; *Hibbertia,* Andr.; *Candollea,* Labill.

Affinities, &c.—Connected with Ranunculaceæ by many important points of structure, these plants are at once distinguishable by the arborescent habit, the persistence of the calyx and the stamens, and the arillate seed; they are even nearer to the Magnoliaceæ, but have no stipules, and the plan of the flower is here 5-merous; they are also related to the Anonaceæ, which, however, have a valvate calyx and ruminated perisperm. Some of the genera (*Hemistemma, Pleurandra*) have all the stamens on one side of the flower; others have them united into separate bundles, probably representing so many divided stamens. A relationship between this Order and the Ternstrœmiaceæ is established by the genus *Sauraja.*

Number and Distribution.—A small group of 17 genera and about 180 species, which are natives chiefly of India, South America, and Australia; a few also of Africa, between the tropics.

Qualities and Uses.—The general character of this Order is astrin-

gency, which renders some of them valuable in Brazil. Some of the *Dilleniæ* are valued in India for their acid juices.

Most of the species of *Dillenia* are very handsome, both as to foliage and blossom; and some of the larger kinds yield hard, durable timber; several species are cultivated in large collections of stove or greenhouse plants in this country, where they are evergreen shrubs; *Delima* and *Tetracera* are stove climbers.

MAGNOLIACEÆ are trees or shrubs, often aromatic, with the leaf-buds mostly sheathed by membranous stipules; leaves alternate, simple; flowers regular, polyandrous, polygynous; thalamus convex, often elongated; calyx and corolla usually coloured alike, in three or more 3-merous circles, imbricated; fruit of numerous dry or succulent, dehiscent or indehiscent carpels; seeds often with a fleshy testa like an aril, and suspended by a long funiculus; perisperm fleshy, homogeneous.—Illustrative Genera: Tribe 1. MAGNOLIEÆ: carpels on a lengthened thalamus, leaves scarcely dotted: *Magnolia*, L. Tribe 2. WINTEREÆ: carpels in a circle; leaves with transparent dots; stipules often wanting: *Drimys*, R. Br.

Affinities, &c.—Closely related to Dilleniaceæ, this Order is distinguished by the 3-merous flowers, and in many cases by its stipules; from the Anonaceæ it is separated by its imbricated corolla and its homogeneous perisperm. The convolute stipules enclosing the leaf-buds of *Magnolia* remind us of the stipules of *Ficus* and other Urticaceæ. In *Magnolia* the course of development shows that the stipules arise from the edges of the leaf-stalk, and that their originally free edges become combined to form a sheath over the bud. The character of the flowers indicates a relationship with Schizandraceæ.

Number and Distribution.—A small group of 8 or 9 genera, and 70–80 species, the greater number of which belong to the Southern States of North America; some occur also in the West-India Islands, in Japan, China, and India. *Drimys* and *Tasmannia* belong to the extreme south of South America, to Australia, and New Zealand.

Qualities and Uses.—Bitter tonic properties in the bark and excessively fragrant blossoms are the most striking qualities of the plants of this Order, which are chiefly handsome trees or shrubs, with broad shining foliage and often very large flowers. The barks of *Magnolia glauca*, *grandiflora*, *Frazeri*, &c. are used in the United States as aromatic tonics; *Michelia montana*, *Aromodendron elegans*, and *Liriodendron tulipifera* have similar properties. The odour of *Magnolia grandiflora*, and of *M. glauca* and *M. tripetala*, is so powerful as to become very oppressive in close places; the last two often induce headache. The species of *Illicium* are aromatic: *Illicium anisatum*, Star-Anise, is so called from the flavour of aniseed in the whole plant, especially the fruit, which yields an aromatic oil. *I. floridanum* has similar properties; and the seeds of *I. religiosum* are burnt by the Chinese for incense. The bark called Winter's bark is that of *Drimys Winteri*; and other species of *Drimys* and *Tasmannia* have similar aromatic and tonic properties. Some of the larger species of *Magnolia*, *Michelia*, and other genera are valued as timber trees in India. Many plants of this Order are cultivated in this country

on account of their beauty or fragrance; some are hardy, as various Magnolias and the Tulip-tree (*Liriodendron*) from North America. Some of the Chinese and Himalayan Magnolias have deciduous foliage and magnificent flowers, such as *M. Campbelli* and *M. Yulan*; others are greenhouse or stove shrubs, such as the species of *Illicium* and the more tender Magnolias.

ANONACEÆ. The Custard-Apple Order.

Coh. Ranales, *Benth. et Hook.*

Diagnosis.—Trees or shrubs with naked buds and no stipules; thalamus usually prominently convex; calyx of three sepals; corolla of six petals in two circles, usually valvate in the bud, hypogynous, sometimes coherent; stamens with an enlarged connective, mostly indefinite, on a large torus; carpels usually numerous, separate or cohering; seed with ruminated perisperm.—Illustrative Genera: *Bocagea*, St.-Hil.; *Xylopia*, L.

Affinities, &c.—This Order is separated from the Magnoliaceæ in general by the absence of stipules, the valvate æstivation of the corolla, and the form of the anthers; but stipules are not universal in the Magnoliaceæ, nor is the corolla always valvate here. The most characteristic features in the Anonaceæ are the trimerous flowers, the double corolla, the form of the anthers and carpels, and the ruminated perisperm, which latter indicates a relationship to the Myristicaceæ, an apetalous Order. Several remarkable deviations from the general character of the Order exist, such as the coherent condition of the horn-like petals in *Rollinia*, the definite number of stamens and carpels in *Bocagea* (which is related to the Berberidaceæ and the Menispermaceæ), and the concave thalamus, the sepals and petals combined to form a hood, and the perigynous stamens of *Eupomatia laurina*. *Monodora* has a single carpel.

Number and Distribution.—Genera about 40, species about 400; natives of the tropical regions of Asia, Africa, and America.

Qualities and Uses.—The Anonaceæ are allied to the Magnoliaceæ by their general aromatic and fragrant properties. The dry fruits are mostly aromatic and pungent, while the succulent kinds are sweet and agreeable esculent fruits. The Custard-apples, Sweet-sops, and Soursops of the West Indies, and the Peruvian Cherimoyas are the fruits of species of *Anona*. The fruits of *Xylopia aromatica* are used as pepper by the African negroes (*Piper æthiopicum*). *Monodora Myristica*, the Calabash Nutmeg, has qualities resembling the true Nutmeg. Lance-wood, used for making shafts, bows, &c., is said by Schomburgk to be the wood of *Duguetia quitarensis*. Some of the species of *Anona*, *Uvaria*, *Xylopia*, &c. are sometimes cultivated in stoves in this country, forming evergreen shrubs.

MONIMIACEÆ are aromatic trees or shrubs with opposite leaves without stipules; flowers axillary, diclinous; thalamus concave, perianth in 1 or 2 circles, tubular below; stamens numerous, springing from the tube; ovaries several, free, and distinct, enclosed in the tube of the thalamus, 1-celled, 1-seeded; seeds pendulous; embryo minute, with thin

spreading cotyledons, on the outside of abundant fleshy perisperm.—This is a small Order of plants belonging chiefly to South America, but occurring also in Madagascar, Java, Australia, &c.; sometimes combined with the next family, and usually referred to the neighbourhood of Lauraceæ, from which they are distinguished by their apocarpous ovaries, but, like the Atherospermaceæ, standing properly in their vicinity of the Anonaceæ, along with Myristicaceæ; for some genera are dichlamydeous. They are also related to Calycanths and Roses, but they differ from these Orders in their opposite exstipulate leaves and albuminous seeds. Baillon unites them with Calycanths and Atherosperms, and places them near Magnoliaceæ, to which their aromatic properties ally them. They are not of importance economically; the fruit of *Boldoa* is eaten in Chili.—Genera: *Monimia*, Thouars; *Citrosma*, R. & P.; *Boldoa*, Juss., &c.

MENISPERMACEÆ. THE MOON-SEED ORDER.

Coh. Ranales, *Benth. et Hook.*

Diagnosis.—Woody climbers, with palmate or peltate alternate leaves, without stipules; flowers diœcious, rarely perfect or polygamous; sepals and petals similar, in three or more circles, imbricated or valvate in the bud; stamens usually 6, superposed to the sepals and petals; pistils 3–6-gynous, on a small thalamus; fruit a 1-seeded drupe, with a large or long curved embryo in scanty perisperm.—Illustrative Genera: *Jateorrhiza*, Miers; *Menispermum*, Tournef.; *Cissampelos*, L.; *Cocculus*, DC.

Affinities, &c.—This curious Order is related to the Anonaceæ and the Berberidaceæ through *Bocagea*, especially when the flowers are perfect. Its nearest neighbours are Lardizabalaceæ and Schizandraceæ, with which the plants agree much in habit. All these approach the Magnoliaceæ; but the habit, the generally unisexual flowers, and the absence of stipules separate them from that family. This Order is very heteromorphous in almost all parts of its structure. The peculiar organization of the wood and foliage deserves attention.

Number and Distribution.—Genera about 30; species (under a hundred) are natives of the tropics of Asia and America, forming woody climbers of great size in the forests. A few are found in more temperate regions, but none in Europe.

Qualities and Uses.—Narcotic and bitter properties of considerable power occur in this Order. "Cocculus Indicus," containing the poisonous principle picrotoxine in the seeds, consists of the berries of *Anamirta cocculus*; *Jateorrhiza palmata* or *Calumba* furnishes "Calumba-root;" different species of *Cissampelos*, as well as *Chondodendron tomentosum*, the roots of which furnish Pareira brava, are used as tonics and diuretics. In India the seeds and roots of "Gulancha," *Tinospora cordifolia*, are used for similar purposes. Species of *Cocculus* and *Cissampelos* are grown in stoves in this country; some of the North-American *Menisperma* grow as hardy climbers here.

LARDIZABALACEÆ constitute a small group, referred by Bentham and Hooker, as also by Baillon, to Berberids, and by De Candolle to

Menisperms. From the former they differ in their diclinous flowers, monadelphous stamens, sutural dehiscence of the anthers, and more numerous ovaries. From the latter they differ in their more numerous ovules and small embryo in copious solid perisperm.—Illustrative Genera: *Hollbœllia*, Wall.; *Stauntonia*, DC.; *Lardizabala*, Ruiz et Pav.

The species are mostly from the cooler parts of Asia and South America. The berries of some are edible. *Hollbœllia* and *Stauntonia* (Nepal) have been introduced as greenhouse evergreen climbers, and are hardy in the south of England.

SCHIZANDRACEÆ form a small family regarded by Bentham and Hooker as a tribe of Magnoliaceæ, from which they differ merely in their climbing habit, exstipulate leaves, diclinous flowers, and fleshy 2–3-seeded carpels.—Illustrative Genera: *Kadsura*, Juss.; *Schizandra*, L. C. Rich.

The species belong to India, Japan, and the S. United States. They are insipid and mucilaginous. *Schizandra coccinea* (North America) is a handsome greenhouse plant; *Sphærostema* (Nepal) has been introduced in stoves.

SABIACEÆ are a small Order of East-Indian plants, related to the Anacardiaceæ, and particularly to the Menispermaceæ, in the circumstance that the sepals, petals, stamens, and ovaries are all superposed to each other, but they have 5-merous hermaphrodite flowers and a syncarpous pistil. By Bentham and Hooker they are placed near Sapindaceæ.

BERBERIDACEÆ. The Berberry Order.

Coh. Ranales, *Benth. et Hook.*

Diagnosis.—Shrubs or herbs, with regular hermaphrodite flowers, with the sepals and petals both imbricated in the bud in 2 or more circles of 2–4 each (fig. 343); hypogynous stamens as many as the petals and superposed to them; anthers opening by 2 recurved valves. Carpel solitary, free; fruit baccate or dry; embryo straight in perisperm.—Illustrative Genera: *Berberis*, L.; *Epimedium*, L.

Affinities, &c.—To Ranunculaceæ this Order is related closely by *Jeffersonia* and *Podophyllum*. *Epimedium* allies the order to Fumariaceæ. The apparent superposition of parts is here due to the decussation of whorls (fig. 343). The connexion with the Anonaceæ through *Bocagea* has been referred to above. They differ from Menisperms, to which their floral arrangements ally them, in their hemaphrodite flowers and small embryo. The remarkable mode of dehiscence of the anthers connects this Order in that respect with Lauraceæ and Atherospermaceæ among the Monochlamydeæ. *Caulophyllum thalictroides*, a North-American plant, is interesting from the development of its fruit: the pericarp dehisces very early, and the two seeds burst out and ripen into naked berry-like bodies with a succulent testa. The leaves of these plants are simple or

Fig. 343.

Diagram of the flower of *Epimedium*: *a*, *a*, bracteoles.

compound, sometimes reduced to the condition of spines. The ripe anthers possess a peculiar irritability, which causes their valves to turn back and burst when touched, so as to allow of the emission of the pollen.

Distribution.—A small Order of about 12 genera and under a hundred species, which are natives of temperate climates in America, Europe, and the northern part of India.

Qualities and Uses.—The bark of the root of some of the Indian species contains a bitter principle, on which account it is used as a tonic in fevers in lieu of quinine. The "Lycium" of the ancients was identical with the extract prepared in India from the wood or root of several species of *Berberis*. The Berberry (the fruit of *Berberis vulgaris*) and the fruits of other species are acid and astringent, and are eaten preserved. The stem and bark are used by dyers, both on account of their astringent properties and as ingredients in a yellow dye. The rhizome of *Podophyllum peltatum* furnishes a resin which has purgative properties, and is much used as a substitute for mercury. The leaves of this plant are narcotic; but the berries are edible. *Berberis vulgaris* is a British plant, often cultivated on account of its beautiful scarlet berries; the evergreen Berberaceæ, *B. Aquifolium*, &c. (*Mahonia*, Nutt.), are also extensively planted on account of their shining pinnate leaves and the grey bloom on their black berries. *Epimedium alpinum* is a rare British plant, found in the northern counties.

NYMPHÆACEÆ. Water-Lilies.

Coh. Ranales, *Benth. et Hook.*

Diagnosis.—Aquatic herbs with cordate or peltate floating leaves, and solitary showy flowers, proceeding from a rhizome growing at the bottom of the water; the partially petaloid sepals and the numerous petals and stamens imbricated in several rows partially or wholly emerge from a large fleshy disk; the numerous carpels combined into a many-celled compound ovary, with radiating stigmas on the top; ovules all over the spongy dissepiments; embryo minute, enclosed in a separate sac at the end of the copious perisperm.—Illustrative Genus: *Nymphæa.*

Affinities, &c.—The relations of this striking Order are varied, and some difference of opinion exists among botanists even as to their position in the two great classes of Angiospermous Flowering plants. The embryo appears to be truly Dicotyledonous; and they naturally approach the Papaveraceæ in the character of the ovary, and the Pæony tribe among the Ranunculaceæ, especially the kinds with a highly developed disk. The character of the floral envelopes and stamens allies them to Magnoliaceæ. The Nelumbiaceæ and Cabombaceæ are immediately connected with them. From a mistaken view of the structure of the seed, regarding the vitellus or amniotic inner endosperm as a cotyledon, Richard assumed that this Order was Monocotyledonous; and although it has proved that this account of the structure of the embryo was incorrect, the plants are so anomalous in many respects, that it is difficult to decide as to their closest relationships. The structure of the rhizomes is quite that of

Monocotyledonous stems; the habit relates them to the Hydrocharidaceæ; and the structure of the ovaries indicates some affinity with Alismaceæ. When, however, we regard the Dicotyledonous embryo and its germination, the quaternary or quinary plan of the flowers, and the netted ribbing of the leaves, together with the close relation to the Dicotyledonous Orders above named, the balance of characters is strongly in favour of its reference to this class. Nymphæaceæ are very interesting in structural respects—as, for example, in the anomalous condition of the rhizomes, the remarkable development of the leaves in *Victoria*, the curious succession of forms between petals and stamens in the flowers of *Nymphæa* and *Victoria*, the various degrees of development of the disk and enlarged receptacle, ranging from *Nuphar* with a superior ovary to *Victoria* with its ovary sunk in the receptacle and its stamens and envelopes raised on an annular disk, the seeds growing all over the dissepiments, and in the peculiar condition of the albumen. *Barclaya* has united petals.

Distribution.—A small family of 4 or 5 genera and 30 to 40 species, which are distributed throughout the world, more rarely in the southern hemisphere.

Qualities and Uses.—These plants are said, on doubtful authority, to be sedative and narcotic. More important characters arise from the presence of starch in the seeds of various kinds of *Nymphæa*, of *Euryale* and *Victoria*, which are used as food. The rhizomes of some Nymphæas are eaten in Scinde, others in Western Africa. Among the most remarkable plants of the Order is the *Victoria regia*, a native of the rivers of equatorial America, with its enormous circular leaves and beautiful flowers. Our native Water-lilies, the white (*Nymphæa alba*) and yellow (*Nuphar lutea*), are both striking objects, and the cultivated *Nymphæa cærulea* and the crimson *N. rubra* illustrate the brilliancy and variety of colour in this beautiful Order. *N. gigantea*, a blue-flowered Australian species, has flowers almost as large as those of the *Victoria*.

CABOMBACEÆ, consisting of only two species, of the genera *Cabomba* and *Brasenia* (*Hydropeltis*), are sometimes separated from Nymphæaceæ, of which they are a reduced form, with definite sepals and petals, hypogynous stamens, distinct carpels provided with styles, inserted on a flattened torus, and containing one or two ovules on the dorsal suture. They are closely allied to Ranunculaceæ, but differ in the embryo enclosed within a double albumen. Both genera occur in America, and *Brasenia* also in the East Indies and Australia.

NELUMBIACEÆ are large aquatic plants, like Water-lilies, but with distinct carpels, forming acorn-shaped nuts separately imbedded in cavities of a large top-shaped thalamus. Seeds solitary, aperispermic. This Order consists apparently of the two species of the one genus *Nelumbium*—*N. speciosum*, supposed to be the Sacred Egyptian Bean, found throughout the East Indies, but no longer met with in Egypt, and *N. luteum* in North America. They are nearly related to Nymphæaceæ, through Cabombaceæ; and both are included in that family by Bentham and Hooker. The enlarged receptacle of the flower is very curious, and the peltate leaves raised above the water on long stalks are remarkable objects. The nuts

are the ripened carpels, which are contained in separate sockets in the top of the thalamus; the seeds have large flat fleshy cotyledons applied against the plumule, which is unusually developed. The seeds, as also the tubers of *N. luteum* and the rhizomes of *N. speciosum*, are esculent, being full of farina at certain seasons.

SARRACENIACEÆ are polyandrous and hypogynous Bog-plants, with hollow pitcher-shaped or trumpet-shaped leaves, and regular polyandrous hypogynous flowers.—Illustrative Genera: *Sarracenia*, L.; *Darlingtonia*, Torr.

Affinities, &c.—These curious plants, chiefly remarkable for their anomalous leaves, forming *ascidia* or pitchers, are few in number, consisting of a few species of *Sarracenia* in the United States, a *Darlingtonia* in California, and *Heliamphora* in Guiana. *Sarracenia* has a very large, angular, peltate stigma, while that of *Heliamphora* is simple and truncate. They are regarded as related to Ranunculaceæ by the 4–5-merous and imbricated envelopes and the numerous hypogynous stamens, while the coherence of the carpels into a compound ovary brings them at the same time near Papaveraceæ; but the placentas are axile. The pitchers are in this case formed by the disproportionate growth of the marginal as contrasted with the central portions of the leaf. They secrete a digestive fluid which causes the solution of insects, &c., which find their way into the pitchers, and which solution is in time absorbed by them.

PAPAVERACEÆ. The Poppy Order.

Coh. Parietales, *Benth. et Hook.*

Diagnosis.—Herbs with milky (white or coloured) juice, alternate exstipulate simple or lobed leaves; flowers regular, 2-merous or 4-merous; sepals caducous; stamens polyandrous, hypogynous, rarely perigynous; ovary syncarpous, 1-celled, with 2 or many parietal placentas.

Character.

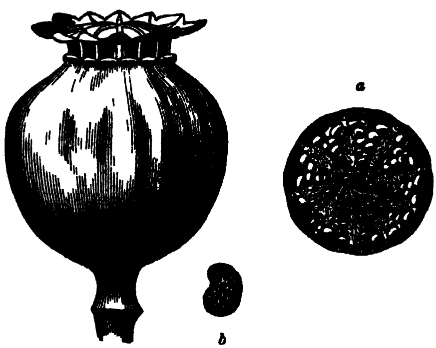
Thalamus flat or expanded. *Calyx*: *sepals* 2, rarely 3, caducous. *Corolla*: *petals* 4, rarely 6, hypogynous, mostly crumpled up in æstivation. *Stamens* free and distinct, indefinite, hypogynous; *anthers* 2-celled, bursting longitudinally. *Ovary* free, composed of 2 or more carpels (very rarely distinct), 1-celled; *ovules* numerous, very rarely solitary; *placentas* broad, parietal, on the projecting incomplete dissepiments; *style* short or none; *stigmas* radiating, double, opposite the imperfect dissepiments; *ovules* anatropous or amphitropous. *Fruit* capsular (fig. 345) with a number of placentas on imperfect septa, or pod-shaped with parietal placentas, the dehiscence valvular or porous; *seeds* mostly numerous; *embryo* minute, straight, at the base of fleshy oily perisperm.—Illustrative Genera: *Chelidonium*, Tournef.; *Papaver*, Tournef.; *Glaucium*, Tournef.

Affinities, &c.—The typical floral formula is $\widehat{S\,2}\ P\,4\ \infty\ A\ \infty\ \widehat{G\,2}$. Taking the common Poppies as types of this order, we find a marked distinction from Ranunculaceæ in the 2-merous calyx, the confluent carpels, and the milky juice; but the first two of these characters do not hold universally, since *Argemone* has sometimes 3 sepals, and *Platystemon* has the carpels more or less distinct, or united only slightly externally. *Bocconia*, with small flowers and no petals, approaches to *Thalictrum*; it has but a single carpel. Monstrous capsules of *Papaver* occur in gardens with the carpels partly free, somewhat as in *Nigella*. This Order is also related to the Nymphæaceæ by the general structure of the flower of *Papaver*; and the dissepiments extend quite to the axis in the Californian genus *Romneya*.

Fig. 344.

Papaver somniferum.
The Opium Poppy.

Fig. 345.



a

b

Capsule of Poppy (*Papaver*) *a*, transverse section; *b*, seed.

Another genus from the same region, *Dendromecon*, has peculiar double-lined parietal placentas, and the capsule bursts into 2 valves with the seeds on the margins, as in Cistaceæ. The quaternary arrangement of the floral envelopes and the pod-shaped ovary of *Eschscholtzia*, *Glaucium*, *Chelidonium*, &c. cause a close resemblance to Cruciferæ and Capparidaceæ, from which, however, there is a marked distinction in the perispermic seeds and the narcotic milky juice. The tetradynamous stamens of Cruciferæ, too, almost always afford a striking character; but a remarkable exception is supplied by an East-Indian polyandrous Crucifer (*Megacarpæa polyandra*), whose stamens are numerous like those of a Poppy. The nearest relatives of the Papaveraceæ are the Fumariaceæ,

which are combined with them as an irregular form by some authors. The agreement is great in many respects; but the Fumariaceæ have irregular flowers, diadelphous stamens, and a watery juice: the genus *Hypecoum*, however, has the corolla nearly regular, and its 4 stamens are distinct: and *Meconella*, in the present Order, has but 4–5 stamens; so that *Hypecoum* is midway, as it were, between the Orders.

The structural points most worthy of note are the varied conformation of the ovary, and the peculiar construction of the stigmas by two lamellæ from adjoining carpels. There is a curious enlargement of the receptacle of *Eschscholtzia*, with circumscissile separation of the coherent caducous sepals in the form of a conical cap. The stamens and petals, moreover, become perigynous in this genus. The sepals in most cases fall off when the flowers expand, so that they must be observed in unopened flowers. In *Eschscholtzia* the receptacle is at first flat with two sepals, which become connate, four petals, three rows of stamens, and four carpels, of which two are abortive (M. T. M.).

Distribution.—The group is not a large one; but the species occur in all parts of the globe, but sparingly out of Europe (in a wild state).

Qualities and Uses.—The milky or coloured juice of Papaveraceæ is generally powerfully narcotic, sometimes acrid. *Papaver somniferum*, the Opium Poppy (fig. 344), is the most important plant of the Order, the opium consisting of the dried milky juice obtained from the unripe capsules (fig. 345). Its native country is unknown; but it is largely cultivated in Turkey and the East Indies. Its seeds yield a fixed oil, which is quite harmless and is used both by itself and as a means of adulterating olive-oil: the oil-cake is also used for feeding cattle. The seeds of *Argemone mexicana* are narcotic-acrid. The yellow acrid juice of *Chelidonium majus*, as also that of *Bocconia frutescens*, is poisonous, and is sometimes used as an escharotic. *Sanguinaria canadensis*, the Blood-root or Puccoon, receives the former name from the red juice of its root, which is employed in North America for its emetic and purgative properties. *Meconopsis nepalensis* is said to be very poisonous, especially in the roots.

Several plants of this Order are wild in this country, as the four kinds of Red Poppy of our fields, the commonest of which is *Papaver Rhœas*. *P. somniferum* is a corn-field weed in many places on chalky soil; and its numerous double varieties are to be found in most gardens. *Glaucium luteum*, the yellow Horned Poppy, grows on our sea-shores; *Chelidonium majus* grows about hedges near villages, and is apparently an outcast from gardens; the other native plants of this Order are less common. *Eschscholtzia*, a Californian genus, is now found in every garden; and *Platystemon*, *Argemone*, and other genera are also cultivated here.

FUMARIACEÆ. The Fumitory Order.

Coh. Parietales, *Benth. et Hook.*

Diagnosis.—**Delicate smooth herbs with watery or colourless juice, dissected leaves, irregular flowers, with 4 partially united petals, 6 diadelphous or 4 distinct stamens; ovary 1-celled, 1-seeded, or several-seeded with two parietal placentas.**

Character.

Thalamus small. *Calyx*: *sepals* 2, caducous. *Corolla*: [illegible] 4, irregular, in 2 circles. *Stamens* hypogynous, rarely [illegible] distinct, opposite to the petals, or 6, diadelphous, the parcels opposite to the outer petals, each with a central 2-celled anther and 2 lateral 1-celled anthers. *Ovary* free, 1-celled; *style* filiform; *stigma* with 2 or more points; *ovules* horizontal, amphitropous. *Fruit*: an indehiscent 1- or 2-seeded nut, or a dry 2-valved or succulent indehiscent many-seeded pod; *seeds* shining, mostly arillate; *embryo* minute, abaxial, straight or curved, in fleshy perisperm.—Illustrative Genera: *Dicentra*, Borkh.; *Fumaria*, Tournef.; *Hypecoum*, Tournef.

Affinities, &c.—The close relationship to Papaveraceæ has been pointed out. Bentham and Hooker indeed include Fumitories under that family. *Hypecoum*, with its four distinct stamens, diverges from the ordinary type immediately towards that Order. The number, form, and arrangement of the floral envelopes mark an affinity to the Berberidaceæ, which likewise have stamens opposite to the petals. A further relationship exists in the direction of Cruciferæ, concerning which, however, authors are at variance, on account of the curious condition of the diadelphous stamens here. The view taken of the morphology of these flowers by Payer, Eichler, Caruel, and others is that there are two sepals formed successively, two outer petals formed simultaneously, two inner petals also formed simultaneously, two outer staminal tubercles, each of which becomes three-lobed; a second staminal whorl is abortive—S 2 P 2+2 A 2+2 G 2. The trilobation of the petals of *Hypecoum* is analogous with that of the stamens. [In *Dielytra* I find in the course of development two sepals, four petals in two rows, two "compound stamens" (of which the [illegible] lobe is largest and bears a two-celled anther, while the lateral ones [illegible] but a single anther-lobe), and two carpels.—M. T. M.] The mo[illegible] which the horned stigmas push themselves against the extrorse anth[illegible] the blossom of *Fumaria*, while the petals cohere by their tips, is wor[illegible] examination, as also are the modifications of the staminal bundl[illegible] *Fumaria*, *Dicentra*, &c. The long pod of *Hypecoum* has transverse spu[illegible] septa between the seeds. The pollen of *Fumaria* is polyhedric.

Distribution.—The species are not very numerous, and are mostly found in the temperate parts of the Northern Hemisphere.

Qualities and Uses.—Mild bitter, sometimes rather acrid, and with slight diaphoretic and aperient properties, but of little importance in this respect. The genus *Fumaria* has a number of rather doubtful species in this coun[illegible] *Corydalis claviculata* is not very rare in woody [illegible] and several tu[illegible]rous-rooted species of *Corydalis* are found as hardy h[illegible] plants in our gard[illegible] *Dicentra* (*Dielytra*) *spectabilis*, a handsome [illegible] species, is now greatly cultivated as an early-flowering greenhouse [illegible] but it is hardy in som[illegible]